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PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

August, 1943
Vol. 22, No. 8

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GRADY TRIPLETT
Editor

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CONTROLLING FACTORS in Petro-chemistry

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A GULF PUBLISHING COMPANY PUBLICATION

THE LOOK BOX

EFFECTIVE with the July issue of PETROLEUM REFINER you observed that the margins around the printed page had been trimmed and that effective with issues before that date a lighter weight paper was being used. Both the reduction in the weight of the paper stock and the reduction of the margins have been made necessary by governmental requirements reducing the over-all tonnage of paper consumed by PETROLEUM REFINER this year. The reduction in paper weight and of margins will make it possible for PETROLEUM REFINER to live within the government's requirements and at the same time permit the editors to publish the same amount of technical and other important material which PETROLEUM REFINER has always carried.

High Octane

FROM plants now operating and building will come sufficient 100-octane-aviation gasoline for military requirements. This opinion was expressed by Bruce K. Brown, assistant deputy petroleum administrator, before a Senate committee last month. While his testimony did not include figures, his references to plants was significant of expansion that will continue until early in 1944.

In January, 1942, only 20 plants in the United States were making this grade of gasoline. Now this highest grade of aviation motor fuel is being made in 47 plants, 4 of which are temporary. Six additional facilities are being added at 28 of the plants, now engaged in this activity with the result that completion of construction will bring increase of 85 percent above the amount being made in June, 1943.

There are 26 other plants where construction is still under way on 100-octane-gasoline capacity. These plants are scheduled to come into production in each of the remaining months of 1943 and the early part of 1944.

When this construction is completed and the four temporary plants are no longer in the program the industry in the United States will have 69 plants where 100-octane-aviation gasoline is being completed.

In addition there are 72 other refining plants, which provide some special products, which go to the units where this grade of gasoline is finished.

Average yield of this gasoline will be around 1 barrel from 7 barrels of crude charged. The extremes on yield will be from 1 barrel out of 3 of crude oil to 1 barrel out of 20 barrels of crude.

You'll Never Get Rich

BACK in April, 1941, the total income of the nation was sufficient to provide each individual with $47.92. Two years later war spending had so stimulated the national income that each individual could have had $85.03 for April, 1943. A gain of 80 percent in the national income had come about through the expenditures of prosecuting a war.

But the two years brought changes in outgo as well as income. In April, 1941, the cost of war spending for that month could have been met by deducting $1.50 from the income of each individual, leaving him with $46.62 for spending and savings. In contrast paying the April, 1943, cost of the

war in that month would have required $53.52 from the average income of each individual. His fund for spending would have stood at only $31.51.

Meanwhile the cost of necessaries, food clothing and shelter, advanced against a lower net income. That average of two years ago, $46.62 with the war cost deducted, was sufficient for necessaries, some durable goods and some savings. The April, 1943, net average $31.51 may leave some for savings and durable goods but it will not equal what could have been done two years previous.

The fact that war costs are not being met currently does not alter the situation. Whether the $53.52 cost of April, 1943, is paid in that month or later, it is going to be paid. When it is deferred, borrowing is necessary and borrowings bear interest.

Getting prosperous from a war is idle hope. What would in peacetime go into refrigerators, homes and automobiles, in wartime goes into guns, tanks and ammunition, which add nothing to the wealth of mankind.

Always Rolling

WHEN tank-car deliveries of oil to the Eastern Seaboard passed 1,000,000 barrels daily, the modern miracle in transportation became commonplace. Deliveries have been around the 800,000 daily total so long it is little noticed.

In part the high figure is maintained because tank cars spend little time in repair shops. So little, in fact that the Office of Defense Transportation reports, "time . . . spent . . . in repair shops . . . results in loss of less than one percent in oil delivered to the East by rail."

Tank-car delivery is a gigantic railroad job, since 70,000 cars are in service. When the layman realizes that these railway systems are transporting millions of tons of other war materials, the precision with which these 70,000 tank cars shuttle back and forth with such little loss in repair time becomes bewildering.

Only a few months before war came responsible officials as well as men in the industry doubted that 20,000 tank cars could be put in this service.

Home Front

IT seems incredible, still it is true that the plant is the safest place for a workman to be. Fewer accidents occur there than at home. Statistics of the National Safety Council for 1942 reveal that 18,500 workmen were killed while at work, while 26,500 were killed while off the job.

Perhaps it is too extreme to anticipate the day when walls of the home will be decorated with posters similar to those found in plants. It will be an excellent condition when men who have learned safe practice while at work begin to take some of that knowledge home. The kitchen ladder needs as wise and cautious use as the ladder in the shop.

Security of Opportunity

EDSEL FORD was born 49 years ago in a house that stood in what is now downtown Detroit. His father was a $30-a-week employee in a power plant engine room, and in his spare hours had just completed building his first horseless carriage.

"Forty years ago Ford Motor Company was incorporated, with paid-in capital of $28,000, of which Henry Ford put up one fourth. The latest official estimate (December, 1941) of the value of Ford stock was $719,000,000, most of it held in the Ford family.

"By the time Edsel Ford finished his public school and college training and started work in his father's factory, Ford was building 180,000 automobiles a year. It grew, while Edsel was president and executive head of the company, to a production of 2,000,000 cars in a single year. In all it produced 30,000,000 automobiles and trucks up to the time it converted its facilities to handle a $4,500,000,000 war program.

"Edsel Ford died yesterday. His father, now nearing 80, cannot be expected to resume full active management. Other men will have to manage the Ford enterprises until Edsel's three sons return from the war and receive the training required for executive leadership.

"There is an old Marxian theory that no man can be enriched without the impoverishment of others. But the vast enrichment of the Ford family has not brought poverty to others. Rather the pioneering in the mass production of motor vehicles has created opportunities for millions in the stimulation of the oil industry, the development of a nationwide highway system, the rebuilding of communities.

"The government, which for decades has derived great revenues from the expanding enterprises of the motor age, will now take the lion's share of whatever estate Edsel Ford leaves. Eventually it will do likewise with Henry Ford's estate. And the nation will continue to benefit by what the Ford family has built.

"The saga of the private enterprise of Henry Ford and his family is one that could not have been written in any other country, or under any other economic system. Nothing like that could have happened, for instance, under a governmental philosophy which gave primary emphasis to 'Social Security from the cradle to the grave.' The principal kind of security under which the Ford enterprise flourished was the 'security of opportunity.'"

—An Editorial from The New York World-Telegram

The Bloom of Petroleum Oils

JACK DE MENT

ALL petroleum oils show a strong blue fluorescence immediately after their recovery and prior to any refining. This blue fluorescence is known to the trade as "bloom," and a certain importance has been attached to it in regard to quality. The blue fluorescence or bloom has been found to be undesirable from a marketing point of view, as the trade associates a green fluorescence with quality. Any very evident blue fluorescence is therefore considered a mark of inferior quality, despite the fact that oil with a blue fluorescence may have equal or even superior qualities to an oil possessing a green fluorescence. Hence, it is desirable from a commercial standpoint to render oils so that they show this green fluorescence or so that a strong fluorescence is made substantially feeble so as to be overlooked in a precursory inspection in ordinary daylight.

The green fluorescence or bloom is most often associated with quality in lubricating oil stock, and certain lubricating oil stocks not having this green fluorescence may acquire a blue fluorescence. This happens when the lubricating stock is generally an oil which has been obtained from a crude petroleum oil by distillation and is called "overhead stock." In the manufacture of lubricating oil from crude oil which is asphalt-free, a green fluorescence is observed in the residue left after removal of the lower-boiling-point oils, even when the residue has had a light cracking to crystallize its amorphous wax. Lubricating oil produced from this kind of stock generally shows the green fluorescence.

Commercial production of lubricating oil showing a green fluorescence has been accomplished by light cracking a lubricating-oil distillate obtained from a California asphalt-mixed-base petroleum oil containing about 4 percent paraffin wax.

In view of the interest in this green fluorescence of petroleum products and the several methods which have been originated to develop it in blue fluorescing oils, it is of interest to petroleum science in general to know exactly what the cause of bloom is, how it can be destroyed and how it can be changed or brought out so as to be properly appreciated.

Many organic substances which possess a closed ring or aromatic structure or one or more unsaturated bonds will show a bright and characteristic fluorescence or glow if placed under ultraviolet light or other radiations. Certain substances may be so markedly luminescent that they will show this property in strong visible light. This is exactly the case in the bloom of petroleum oils. Resonating structures, covalent linkages, and certain of the more complicated types of bondings may so respond to radiation striking them that, in terms of the physicist, they may have their energy raised to an upper level. This increase in total internal energy may arise essentially in additions to the energy of electrons, and to the energy of the vibrational and rotational movements of the molecules in the system. When this energy state is destroyed the energy is released as light and the system drops back into its original configuration.

Should a number of like molecules be closely neighboring, the absorption of energy may be insufficient to cause fluorescence, as an equal distribution to all occurs before any one can build to a stage where the release of light is permissible. This is seen in many solids and in concentrated or pure liquids. Gases, where the particles are well dispersed, luminesce strongly in many cases and this view is basic in the explanation of the luminescence mechanism. In liquids, however, there is one region where an appreciable fluorescence can occur without interference from near-by particles.

This region in a contained liquid where fluorescence will be seen under optimal conditions is at the surface and where the liquid comes in contact with the sides of its vessel. Hence, in petroleum the fluorescence or bloom is best observed at the meniscus, while it is being poured, or at the juncture with the sides of a glass vessel. If, however, the petroleum is placed in an organic solvent and sufficiently diluted, a marked fluorescence may be seen throughout the body because the emitting particles have been so dispersed that they can release their light without absorption by neighboring molecules. As simple as this fact may appear, actually it makes possible the detection of petroleum in drill core, water, and in other media in extremely small amounts.

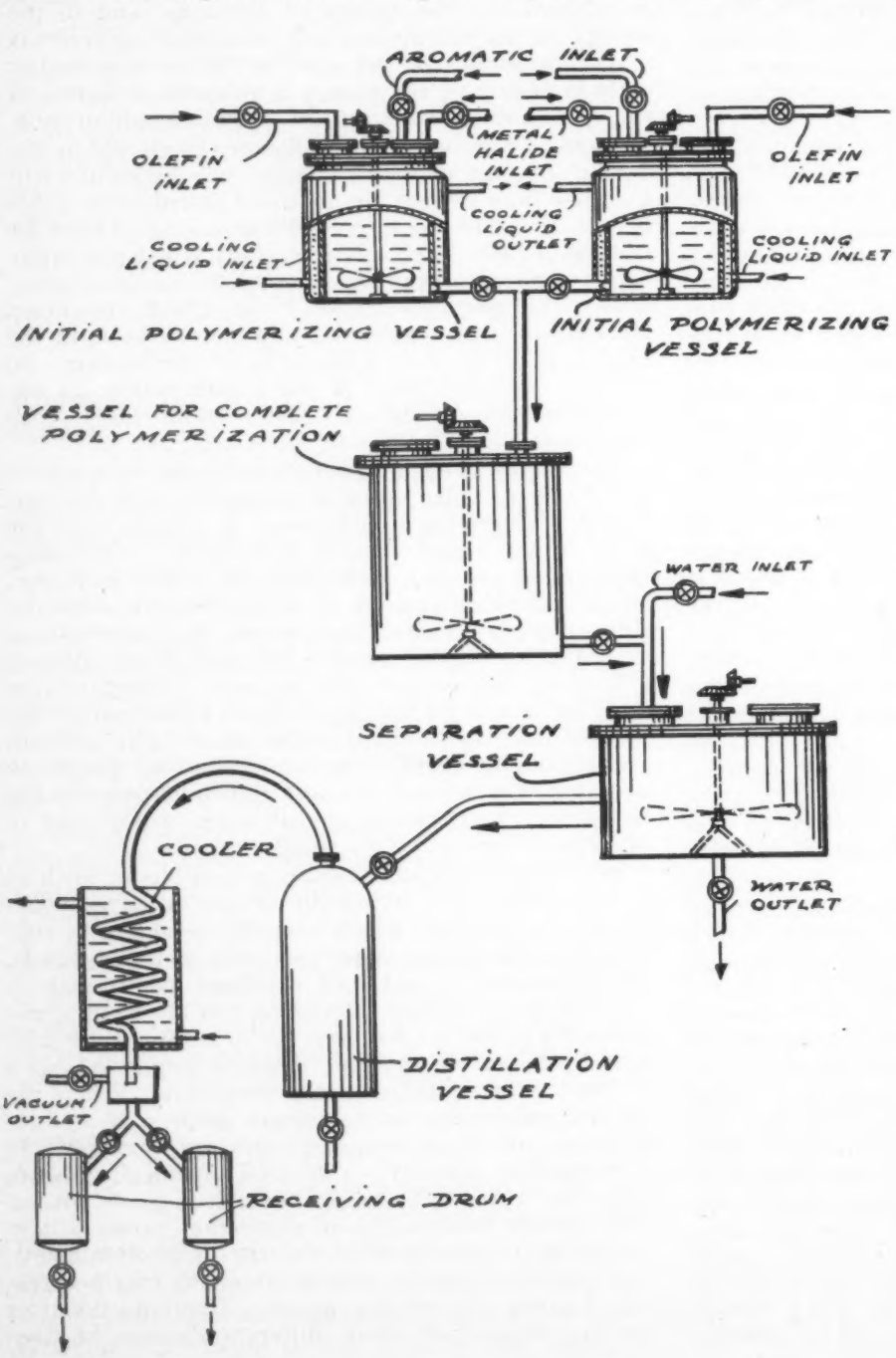
When the fluorescence appears as a bloom, such as at the surface, it is technically known as *surface fluorescence,* a condition which is usually produced by concentration quenching. When the entire body luminesces, the phenomenon is spoken of as *volume fluorescence.*

Actually the surface fluorescence or bloom of petroleum oils is due to the presence of a number of aromatic substances, any one of which might exhibit a marked light emission in the pure state. When the natural substances in petroleum show a blue fluorescence they must either be extracted or reduced to a negligible quantity, or treated chemically before they can be made to show the desired green bloom. The surface fluorescence of petroleum varies widely according to the crude stock, the number, amount, and nature of organic substances which may be present. During the refining process, fractions taken at various stages will show different degrees of fluo-

rescence, usually decreasing until the very light constituents remain. These light constituents, benzene, toluene, and others of a related nature, show no bloom when pure, but the slightest presence of a markedly fluorescent substance may render them appreciably fluorescent. Hence, interest in the commercial appreciation of a green fluorescence centers on heavier stocks, such as lubricating oils. There is little commercial importance at present attached to the bloom of most other petroleum fractions, although this property may be of the utmost importance from a purely scientific standpoint.

In imparting to oil the desired green fluorescence a number of methods have been developed. It has been found that by polymerization of aromatic hydrocarbons containing more than one nucleus under appropriate conditions of temperature and in the presence of catalysts of the Friedel-Crafts type, substances are obtained which dissolve in mineral oil or certain other organic solvents to give a liquid which fluoresces green. These substances have a tarry or asphaltic consistency and do not have uniform composition, rather, being made up of a number of related substances which all fluoresce green. They can be dissolved in lubricating oils with a little warming, but they may be unsatisfactory for widespread use because they precipitate again on cooling. When precipitation takes place the green fluoresence is of course lost.

However, it has more recently been found that green fluorescing substances can be produced with the desired solubility, and even at low temperatures. when olefines of wholly aliphatic constitution, and which are liquid at ordinary temperature, are condensed with polynuclear organic substances in which none of the nuclei is saturated with hydrogen. This condensation is brought about at an elevated temperature in the presence of aluminum chloride. Best results have been obtained by using polynuclear substances in which the aromatic nuclei do not have substituents. The polynuclear substances which have found satisfactory use are naphthalene, anthracene, or polynuclear heterocyclic compounds such as carbazol. They may be added to heavy oils, lubricating oils, liquid motor fuels, and other liquid hydrocarbon fractions so as to impart to them the desired green fluorescence.



The olefines which can be employed as starting materials in the condensation include the liquid products obtained by cracking paraffnic hydrocarbons, such as hard or soft paraffin, petroleum, or oils primarily consisting of paraffinic hydrocarbons. The olefines derived from the dehydration of certain alcohols may also be used; the alcohols should have an aliphatic chain length corresponding to the olefin desired, as in octyl alcohol.

The condensation of olefines and hydrocarbons of the polynuclear aromatic type is effected at temperatures between 70° and 250°C., and most preferably between 125° and 200°C. In order to carry off the large amount of heat evolved during the condensation, the treated materials are preferably diluted with an inactive solvent, such as the benzine fraction boiling between 150° and 200°C. Fractions boiling at higher temperatures may also be employed as the solvent. The system is cooled externally as well.

The quantity of aromatic hydrocarbons employed should be greater than 20 percent of the amount of the olefines employed, but is advantageously not greater than 70 percent of the amount of olefines, since a surplus does not take part in the reaction, but acts only as a diluent and would have to be distilled from the resulting

condensation product. The fluorescence intensity caused by a definite amount of the condensation product is greater than the amount of aluminum chloride used. Preferably from 20 to 60 percent aluminum chloride with reference t othe amount of the initial olefines to be condensed are employed. With greater amounts of the catalyst the resulting, condensation products give a fluorescence with a slightly bluish tinge. The products obtained by this method usually have a mean molecular weight of between 600 and 800.

The fluorescent substances obtained in the condensation are thickly liquid, viscous products which dissolve at room temperature in hydrocarbon oils of naphthenic or paraffinic base, such as in lubricating oils or in benzene. No precipitation or resinification occurs when these substances are mixed with oils The oils with such materials in them are wholly clear, and an addition of from 0.1 to 0.2 percent is sufficient to render an oil green fluorescing so that it closely resembles the best grade Pennsylvanian oil. These oils have a red color by transmitted light and the green bloom shows in reflected light.

The accompanying illustration shows a schematic layout of the equipment for carrying out this process. The legend which explains the functioning of the equipment is given in the illustration. Several examples of the practice for obtaining these products by the apparatus might be given but one will suffice for illustration.

One kilogram of a fraction consisting for the most part of olefines which boil between 90° and 150°C. at 2 millimeters pressure and which have been obtained by cracking soft paraffin wax are subjected to condensation with one kilogram of naphthalene in the presence of 0.4 kilogram aluminum chloride. The reaction product having attained a temperature of 180°C. is allowed to cool down, then stirred with water which frees it from the aluminum hydroxide which forms. The reaction product is then heated to 150°C. at a pressure of 2 millimeters, 0.05 kilogram of oil being distilled as first runnings. The liquid residue, weighing 1.9 kilograms, represents an excellently flourescent substance which is soluble in lubricating oils and in benzene. If a mineral oil having a yellow color is mixed with 0.15 percent of this substance the product shows a remarkable green fluorescence and appears red in transmitted light. The product made in this manner, however, may not be entirely satisfactory as a bluish tinge may develop in the oil when over-exposed to light.

This objection is overcome by employing for the condensation not only condensants of the Friedel-Crafts type, such as the aluminum chloride, but also halides of alkali and alkaline earth elements, such as sodium chloride or bromide, potassium chloride, or cuprous, calcium, or mercurous chlorides. These salts do not catalyze the reaction but diminish the action of the condensing catalyst. The method of working is the same as when using the catalyst without the additions. The products obtained, when added to an oil for example in an amount of from 0.2 to 1.0 percent impart a good fluorescence of the desired shade and of good stability to light and oxidation.

It has been found that certain substances extracted from coal tar, coal tar pitch, water gas tar, and high-boiling distillates of water-gas tar, will impart to a lubricating oil stock a green fluorescence and will produce a stock which appears to be better than blue-fluorescing stock in quality and color. Lubricating oils not possessing the green fluorescence may have commercial grade fluorescent substances other than aromatic hydrocarbons added to them so that this quality will be brought about. Such substances of potential value include certain of the flavines, xanthene and fluorescein dyestuffs, and members of the acridine series dyes. In general these substances have not been employed widely because they have too high a cost. Before lubricating oil can be dyed so as to show a green bloom, a substance must be found which is economical and preferably manufactured as a by-product of petroleum refining. This is why greatest emphasis has been made upon the polynuclear aromatic hydrocarbons, from anthracene on up. There are many polynuclear aromatics which fluorescence strongly, and of these anthracene containing small amounts of chrysene is perhaps the most widely known. The perylenes and coronenes fluoresce so brightly that they can be detected in dilutions as great as one part in a million.

It is not of incidental interest that when examining a commercial lubricating oil for its fluorescence or bloom to know of the correct manner in which this should be performed. In the absence of any auxiliary equipment, and for a quick study in daylight, fluorescence is best appreciated if the oil is smeared or poured in thin layers onto a dark or not brightly colored plate and inspected in bright daylight from an oblique angle. The bloom will be seen at the surface and at the edges of the spot better than at any other part of the oil. Oil emitting from a fine jet may also be inspected for bloom, but this method is not as satisfactory.

For a more thorough laboratory study, the *relative bloom* method of the writer can be employed. This consists of dissolving a given amount of the oil in a nonfluorescent solvent and measuring the band edges of its fluorescence spectrum excited by 3650A ultraviolet light. The sample is then placed in a photoelectric fluorimeter and the intensity of its luminescence determined. With these facts a comparison can be made very easily with known oils from different refiners and localities and it is sometimes possible to determine whether the bloom has been imparted artificially or is due to the natural make-up of the oil. In order to effectively appreciate a fluorescence spectrum by spectral determination, and in the use of the fluorimeter, details on the exact procedure and equipment to be used should be sought in special texts in the field of fluorochemistry. Work of this kind can entail interference by a number of factors and when any gravity is to be accorded the result it should be conducted very carefully by an experienced chemist who is thoroughly familiar with fluorochemical processes and techniques.

LITERATURE CITED

U.S.P. 2,028,472 and 2,071,521 to I. G. Farbenindustrie and now in the hands of the Alien Property Custodian. These two patents deal with the method and apparatus given in the drawing in this paper.

U.S.P. 1,708,563 and 1,708,602 to Pan American Petroleum Company.

J. De Ment, *Fluorochemistry*, New York: 1943. This work will give a foundation in the theory and cause of bloom.

Nomograph for Finding k in Smoker's Equation for Binary Distillation

CARL H. BISESI

Technical Service Division, Standard Oil Company of New Jersey

CHEMICAL engineers concerned with problems and studies in fractionation have not devoted sufficient attention to the method of calculation presented by Smoker[1]. Smoker has developed a mathematical expression in place of the step-wise procedure of McCabe-Thiele for the determination of the number of theoretical plates required in the separation of binary mixtures. The Smoker Equation assumes Raoult's Law and an essentially constant relative volatility.

The original article should be consulted for a description of Smoker's method. However, use of the method involves the solution of the following quadratic equation in order to obtain a value which has been called k:

(1) $m(\alpha-1)k^2+[m+b(\alpha-1)-\alpha]k+b=O$

where k is the root between O and 1, and,

(2) $m=R/(R+1)$ (for rectifying section)
(2a) $m=[Rx_f+x_p-(R+1)x_w]/(R+1)(x_f-x_w)$ (for stripping section)[2]
(3) $b=x_p/(R+1)$ (for rectifying section)
(3a) $b=x_w(x_f-x_p)/(R+1)(x_f-x_w)$ (for stripping section).

This k value is needed to calculate several quantities which appear in the final form of Smoker's Equation. Once k is obtained, the equation can be solved readily.

In order to eliminate repeated solution of the quadratic of (1), which would be very tedious if it had to be done a substantial number of times, a nomograph has been prepared which quickly gives k for any combination of m, b, and α (up to α=20). The fractions m and b are calculated from (2) or (2a) and (3) or (3a), located on the chart, and joined by a straight line. K is read at the intersection of this line with the appropriate α. The nomograph may be used for both the rectifying and stripping sections of the tower.

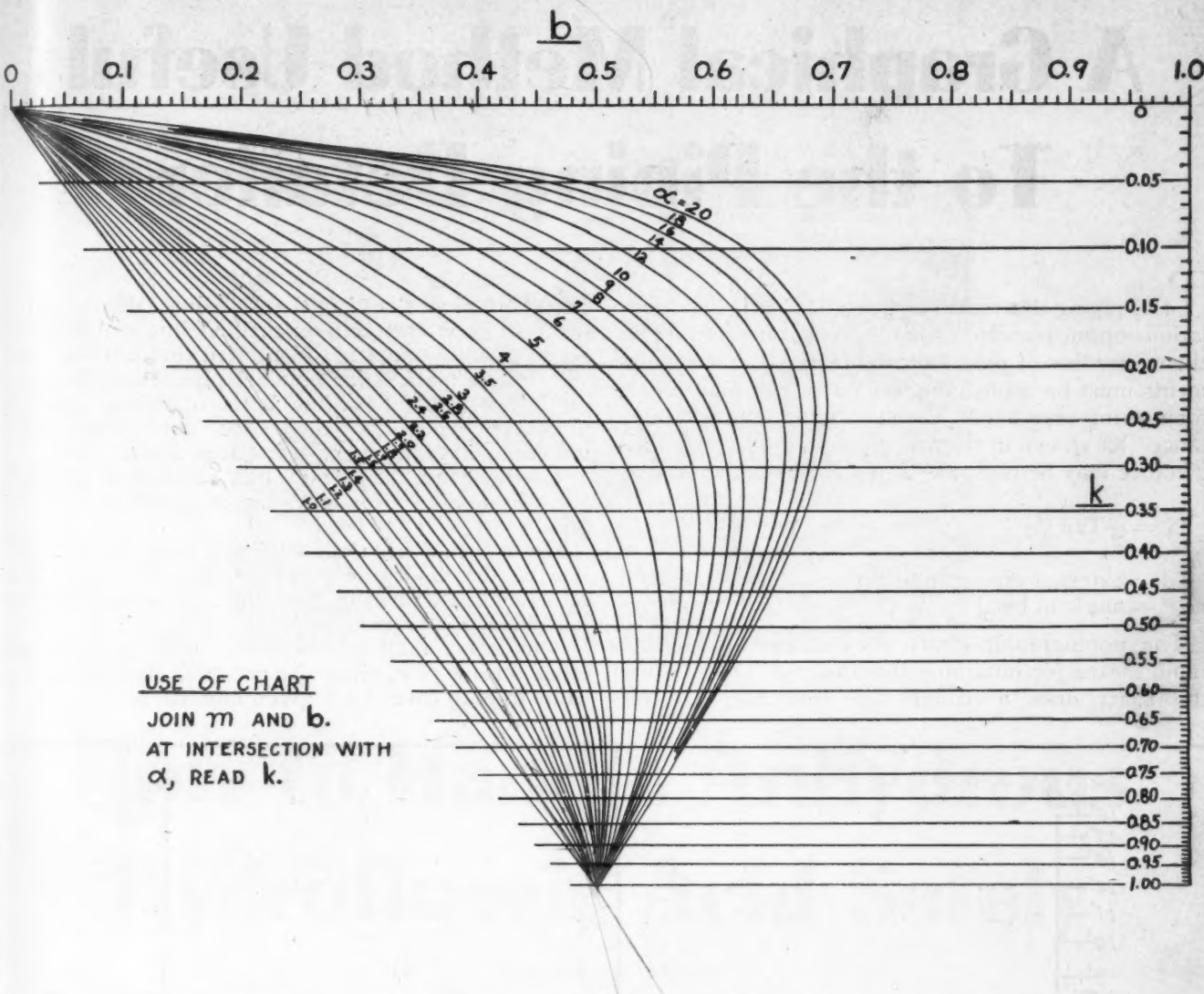
The Smoker Equation finds its greatest application in distillations involving difficult separations, since for these (a) the step-wise method becomes extremely laborious and time consuming, and (b) the equation is at its highest validity because the assumption of constant relative volatility is justified. Hence, for difficult separations, Smoker's method is an accurate and rapid means for designing, analyzing, and controlling the operation of fractionating towers. Although its accuracy for the less difficult separations is not as great as for the former case, it nevertheless remains a valuable equation for indicating tower performance. Many multicomponent distillations may often be considered as primarily a separation between two of the components present and here again Smoker's Equation may be used to advantage as a guide in controlling fractionation. It is worth-while to note that because Smoker's method resolves all of the distillation variables into a single equation it possesses considerably greater flexibility than the step-wise procedure.

Nomenclature

R = Reflux ratio.
x_f = Mol fraction of lower boiling component in feed.
x_p = Mol fraction of lower boiling component in overhead.
x_w = Mol fraction of lower boiling component in bottoms.
α = Relative volatility.
k = A factor depending upon m, b, and α.
m and b are defined by equations (2), (a), (3), and (3a)

[1] Smoker, E. H., "Analytic Determination of Plates in Fractionating Columns." *Trans. A.I.Ch.E.* Vol. XXXIV (1938), p. 165.

[2] When feed is not at boiling point, the x coordinate of the intersection of the operating line in the rectifying section and the q-line is used in place of x_f.



NOMOGRAPH FOR FINDING k IN SMOKER'S EQUATION FOR BINARY DISTILLATION

FOR RECTIFYING SECTION

$$m = \frac{R}{R+1}$$

$$b = \frac{X_p}{R+1}$$

FOR STRIPPING SECTION

$$m_1 = \frac{RX_F + X_p - (R+1)X_W}{(R+1)(X_F - X_W)}$$

$$b = \frac{(X_F - X_p)X_W}{(R+1)(X_F - X_W)}$$

α = RELATIVE VOLATILITY

m

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

A Graphical Method Useful To the Piping Detailer

THE piping draftsman and detailer bases his calculations on measurements made along, and parallel to, the center line of pipe. But, for fabrication, measurements must be made along the outside of pipe. Thus, for making pipe bends, the shop must know the distance "X" shown in the accompanying diagram. This distance may be computed from the formula,

$$X = \frac{d}{2} \operatorname{Tan} \frac{\alpha}{2}$$

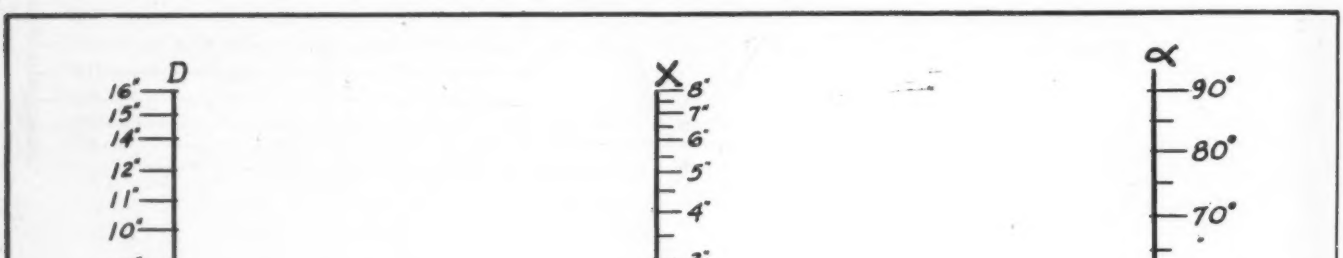
d = external diameter of pipe
α = angle of bend

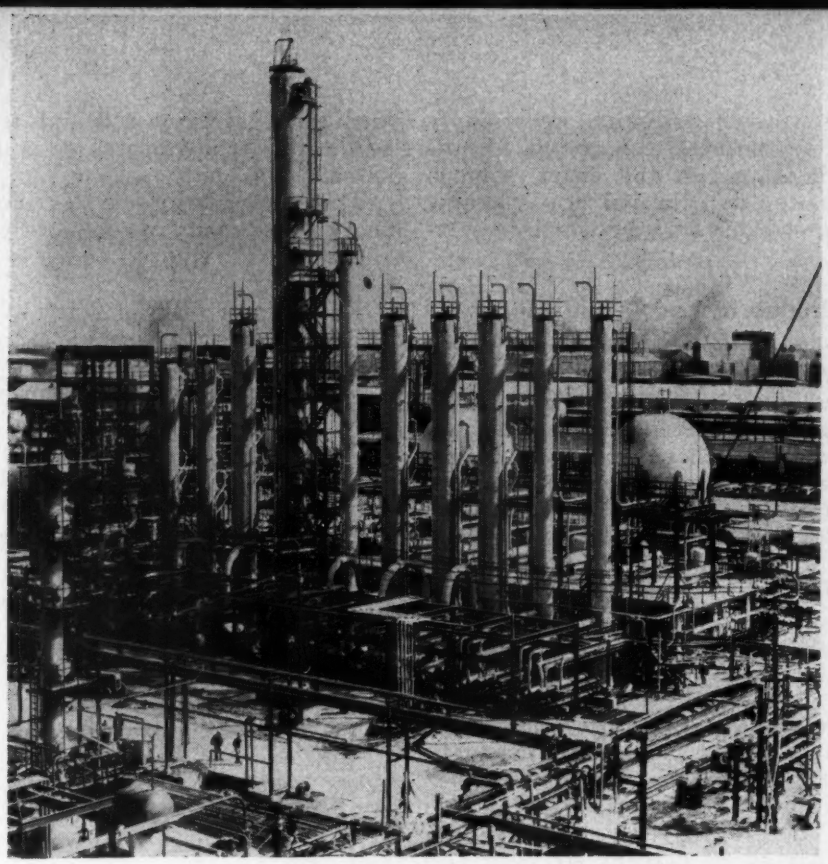
The nomographic chart shown here provides a rapid means for obtaining this distance "X." To use this chart, draw a straight line from the "D" line (nominal pipe size) to the "α" line (the angle of bend). The intersection on the "X" line will give the required solution. It is to be noted that although the "D" line is marked for nominal pipe sizes, distances on it are laid off on the basis of actual external diameter. Thus the draftsman need work with nominal sizes only when using this chart.

To illustrate the use of this chart, we will find the distance "X" for a 25-degree bend on 3½-inch pipe.

Draw a line from the 3½-inch point on the "D" line to the 25-degree point on the "α" line. The intersection with the "X" line is approximately 7/16-inch, the required value.

This chart may be used for both standard and extra strong pipe, since the external diameter is the same in both cases for a given nominal size.





Courtesy, The Lummus Company

How to Handle Anhydrous Hydrofluoric Acid Safely

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ANHYDROUS hydrofluoric acid is a new oil-refining chemical. As with any new substance, users are asking a number of questions concerning handling, storage, and use. The answers are not always easy to find. Some information is available in the literature, some must be taken from private correspondence with other producers and users, still others must be drawn from personal experience.

These observations arise from a desire to be of assistance by covering in the literature a specific phase of this work; namely, handling and storing anhydrous hydrofluoric acid in industrial plants. Admittedly it is a hazardous commodity, if carelessly handled and used in improper equipment, may cause serious injury to human beings, and property damage. When the necessary precautions are taken and suitable equipment provided, no unusual hazard exists. It is not different in this respect from other chemical commodities such as ammonia, chlorine, tetraethyl lead, etc., now employed by industry without significant effect on safety.

The writer has been technically associated with the production and shipment of hydrofluoric acid since 1919, and in 1931 supervised the manufacture and shipment of the first anhydrous hydrofluoric acid produced commercially in the United States. In the preparation of these remarks he has borrowed liberally from the published and written work of others, grateful acknowledgment of which is now made. The literature is not complete—we have much to learn.

THIS article on the safe handling of anhydrous hydrofluoric acid rounds out a consideration of this chemical as a catalytic agent. In the June and July issues of *Petroleum Refiner* Professor J. H. Simon, Pennsylvania State College, dealt with this acid as a catalyst, with particular emphasis on its application in alkylation.

With the exception of process details, which must be kept secret until censorship can be relaxed, these articles brought the refining industry up-to-date on the newest of its catalytic agents.

In this issue the practical matter of handling anhydrous hydrofluoric acid safely is extensively outlined. The author, Charles M. Fehr, has been identified with the manufacture and handling of hydrofluoric acid for 20 years. Recently he has been concerned with its adaptation in petroleum refining.

His observations were given before a meeting of the technical group of the Western Petroleum Refiners Association, Tulsa, July 9, 1943.

The information given herein is limited accordingly although it is based on the best technical facts now available. Some of it is proven and exact, some a reasonable approximation and the balance is "know how." It is offered for what it may be worth in solving your problems.

History of Hydrofluoric Acid Manufacture

Although hydrogen fluoride was discovered in 1768 by Margraff, it was not available for commercial use in its anhydrous form until 1931, being used before that time in aqueous solution of strengths varying from 30 percent to 60 percent hydrofluoric acid by weight. Its manufacture in the United States may be placed prior to 1876 through an interesting quotation from an old bill of sale dated April 10, 1876. It was signed by one John P. Wildsmith and transferred to one Sydney Newsham certain materials including "fluoric" acid.

Before considering its various properties it is well to point out that at 98 percent or higher anhydrous hydrofluoric acid is an entirely different compound as compared with the weaker forms previously used in commerce. As it increases in strength, changes take place in gravity, boiling point, freezing point and, the most important of all, its attack on materials of construction. The gravity rises to a maximum of approximately 1.259 at 80 percent strength and then drops off as the strength increases. Between 65 and 80 percent the corrosive characteristics of hydrofluoric acid change. For example, below 65 percent it has a low corrosion rate on lead, while above 65 percent it attacks lead rapidly. Again, below 60 percent it has a high corrosion rate on steel, while above 80 percent practically no action occurs on steel of good composition. Similarly, rubber, Neoprene and many synthetic plastics show excellent resistance to weak hydrofluoric acid but are increasingly attacked in strengths above 60 percent and 80 percent.

As we are concerned here only with anhydrous hydrofluoric acid as it is received and used in the refinery, and not in the alkylation process itself, it will be well to remember that we are dealing with anhydrous hydrofluoric acid and that its problems are peculiar and different from the problems involved with the lower strengths. It may be regarded as on the border-line between a true compressed gas and a corrosive liquid. As most of the experience of equipment manufacturers has to date been concerned with the handling of hydrofluoric acid below 60 percent, many of the exasperating corrosion problems previously experienced will be eliminated with this form of hydrofluoric acid.

Principal Properties of Anhydrous Hydrofluoric Acid

Certain properties have direct relationship to the problem of handling and are briefly outlined:

Freezing point, approximately —117.4° F. This unusually low value assures that it may be stored and used in process at very low temperatures without the problem of solidification. For example, 66° baumé sulphuric acid (93.19 percent H_2SO_4) freezes at —29° F. Likewise, 98 percent H_2SO_4 freezes at +36° F.

Boiling point, approximately 66.9° F. at atmospheric pressure. This is ideal, assuring ease of handling either as a liquid or a gas.

The vapor pressure, which is about 17 pounds per square inch, gauge, at 100° F. assures storage in medium pressure vessels and its retention as a liquid at elevated temperatures without objectionable pressures.

The low viscosity and surface tension causes the acid to flow easily in comparatively small pipes. Less equipment is required and less time is consumed in transferring.

The heat of reaction with water is approximately 11,500 calories per formula weight. Less heat of reaction will be evolved than with other alkylation catalysts and temperature control should be simplified.

Heat of vaporization is about 6000 calories per formula weight, assuring its removal from reaction products by application of a small quantity of heat.

Satisfactory Materials of Construction

In our first work on the production of anhydrous hydrofluoric acid in 1931, laboratory and pilot-plant tests were conducted to determine roughly which materials were satisfactory or unsatisfactory. While these tests were helpful in the development of an entirely new process they did not tell the complete story. It was only after the process was actually in full-scale operation that real progress was made in determining desirable materials of construction. We found that because of its low corrosion rate mild carbon steel was excellent for handling anhydrous hydrofluoric acid and was the logical material for storage tanks, pipes, fittings, valves, and pumps. This conclusion has been sustained by experience during the past 12 years and today it may be positively stated that steel tanks for storing anhydrous hydrofluoric acid have been in service for 10 years and are in good condition today. The shipping-container problem has been solved by the use of steel. Apparently a protective coating forms on the surface of the steel, inhibiting further corrosion. This becomes a problem on valves in that it will cause valves to freeze unless operated at fairly frequent intervals. This is probably because the film cements moving parts together. By opening and closing valves at least twice each shift this operating difficulty may be avoided. Obviously, double-valving is required.

Some steel is more resistant to anhydrous hydrofluoric acid than others. A thoroughly deoxidized, dead-melted, or killed steel in which the non-metallic inclusions are absolutely at a minimum is the ideal steel. Bessemer steel is not desirable due to lack of precise control.

Our experience with Monel has been satisfactory and it appears the best of all commercially available metals for anhydrous hydrofluoric acid. However, with the present restrictions on the use of nickel, steel is preferable wherever possible. For the fabrication of laboratory equipment for handling anhydrous hydrofluoric acid, such as sample bottles, valve parts, especially valve stems, and for parts in contact with weaker acid, Monel metal is ideal and should be used.

Copper has been found satisfactory in various parts of the process. Under proper conditions it is a close second to Monel. It is, however, attacked in the presence of sulphur dioxide and oxygen and, where these are present in the anhydrous hydrofluoric acid, copper is unsatisfactory. We recently examined a copper coil, put into operation in 1931 for two years and recently returned to service, finding it in an excellent state today. Copper tubing is excellent, especially where flexible connections are needed.

In addition to these metals, silver and platinum

may be employed where construction justifies. Platinum is probably the most resistant of all metals to anhydrous hydrofluoric acid and silver has very excellent resistance in the absence of sulphides or appreciable quantities of sulphuric acid.

Readers are cautioned to interpret these recommendations as applying to anhydrous hydrofluoric acid only, since steel is not satisfactory for hydrofluoric acid below 60 percent. Copper, Monel, silver and platinum are resistant to the weaker acids except under the specific adverse conditions noted in the foregoing. Platinum and silver are particularly useful for small parts or for special members, such as frangible discs.

Unsatisfactory Materials of Construction

Among the unsatisfactory materials of construction, probably the most readily attacked are those containing silica, such as glass, porcelain, enamelware, asbestos, certain silica cast irons, etc.

While lead is serviceable for acids below 65 percent, under normal conditions it is unsatisfactory for strong acids, especially anhydrous hydrofluoric acid.

Cast iron is more resistant to anhydrous hydrofluoric acid than lead but, probably due to silica inclusions, it is not a generally satisfactory material. Cast-iron fittings will last only a comparatively short time before replacement.

Among other materials found unsuitable for anhydrous hydrofluoric acid are wood, which chars instantly; rubber, which polymerizes and hardens, and most plastics. We have hopes, however, of a non-flexible plastic which is now being studied.

Shipping Containers

Anhydrous hydrofluoric acid is regulated by the Interstate Commerce Commission as a hazardous article, being classified as one of the strengths of hydrofluoric acid. Strictly interpreted it is not a compressed gas although its shipping containers are compressed-gas pressure vessels. A compressed gas is defined in ICC regulations as being any material with a pressure at 70° F. exceeding 25 pounds per square inch, gauge. Anhydrous hydrofluoric acid is only ½ pound, gauge, pressure at 70° F. Its permitted shipping packages are:

Cylinders—ICC Spec. 3, 3A, 3B, 3C, 3E, 25 (all seamless steel cylinders of various types); 4, 4A, 4B, 4C, 38 (forge welded but not brazed cylinders of various types). Cylinders are filled to 85 percent of their water capacity, which means that a cylinder holding 100 pounds of water brimming full can be loaded with not more than 85 pounds of anhydrous hydrofluoric acid. We favor cylinders holding 235 pounds net, weighing 428 pounds gross.

Single-Unit Tank Cars—Forge-welded pressure vessels mounted on a running gear and forming a part of a complete tank car, specifically ICC Spec. 105A-500, better known to the refining industry as the ammonia, chlorine or propane car.

Shipping-Container Valves—All-steel or brass valves are in service. The all-steel ammonia cylinder valve has been specially adapted to anhydrous hydrofluoric acid service by replacing the tin seat with copper and the provision of suitable packing. Anhydrous hydrofluoric acid cylinder valves are not fused. Valve outlet nipple openings are ⅜-inch American National Standard female taper pipe threads.

Like the chlorine and ammonia tank car domes, the anhydrous hydrofluoric acid car is fitted with two gas valves on the cross axis and two liquid eduction valves on the longitudinal axis of the car. A specially fitted safety valve provided with a platinum protected frangible disc is centered between the four valves and set to be gas tight at pressures below 180 pounds per square inch and wide open at 225 pounds per square inch, gauge. The outlet nipple opening connections of the two gas and the two liquid eduction valves are 1-inch American National Standard taper female pipe threads.

These cars are insulated and may be filled to 90 percent of their water capacity. Cars available from our works hold 11.6 tons and 21.6 tons respectively.

Storage Vessels

Steel tanks are the logical storage vessels for anhydrous hydrofluoric acid and should be of welded construction conforming to paragraph U-68 of the ASME code for unfired pressure vessels. Proper outage must be provided and insulated storage tanks should not be loaded to more than 90 percent of their water capacity—non-insulated tanks to 85 percent. Where feasible scale mounted tanks are more preferable than level indicators because of minimum error and trouble. Bottom outlets on storage tanks should be avoided wherever possible by loading and unloading through a standpipe. When bottom outlets on storage tanks are unavoidable a drop plug valve should be provided as protection in case of valve failure. Storage vessels must be provided with a safety valve set to open at 2/3 of the working pressure of the tank and protected by frangible platinum discs.

Transfer of Acid

Transfer of anhydrous hydrofluoric acid is a major problem which may be accomplished in two ways—by pressure padding with dry air or an inert gas, such as butane, or by pumping.

Pressure padding is indicated for the transfer of a volatile liquid such as anhydrous hydrofluoric acid from tank cars and storage tanks equipped with well pipes. Pressure on the receiving tank must be depressed by occasional venting of gas from the top of the tank. In the manufacturing plant this gas is recovered in the absorbing system but in the refinery should be absorbed in an alkaline scrubber. The chief advantage of pressure padding is the elimination of pumps and bottom outlets on storage tanks. The packing problem on acid pumps is serious where strict acid specifications preclude the use of a special liquid-hydrocarbon pressure-seal packing gland.

The alternate method of transfer is by means of centrifugal or gear pumps. For satisfactory operation these must be fed from a bottom outlet in a tank in order to avoid vapor lock. Packing problems on centrifugal pumps used in the refinery are minimized by specially designed liquid-hydrocarbon pressure-sealed glands.

Flowmeters and weigh tanks are both used for the measurement of acid to process.

Piping

Extra heavy seamless-steel pipe and forged-steel fittings are preferable for handling anhydrous hydrofluoric acid. Welding makes the ideal joint, provided the weld is homogeneous and free of slag and oxides. Welded fittings should be used wherever possible. If threaded joints are used on small pipe, the threads

should be carefully cut, pulled up tight and seal welded. Some designers do not seal weld pipe under ½-inch size, reporting threaded joints satisfactory.

For connecting pipe larger than 2-inch ring flanges with soft iron gaskets are satisfactory. Neoprene or Vistanex impregnated asbestos gaskets have been successful especially on small lines.

Heavy copper tubing is satisfactory for flexible connections to scale mounted tanks.

Valves

Needle, globe and gate valves have been used successfully. We prefer a needle valve due to sturdy construction. Steel is an excellent construction material and valves may be machined from bar stock or forged. Cast steel valves if used must be carefully examined for porosity and sand holes. Deep stuffing boxes and outside threads are desirable. The principal difficulty with all steel valves is freezing of the seats and corroded stems. Regular operation of the valve reduces freezing and Monel-trim valves, especially stems, are an excellent freezing preventive. Corroded stems may be avoided by keeping the packing glands tight.

Our experience with lubricated cocks in anhydrous hydrofluoric acid service has not been satisfactory, due to an unsatisfactory lubricant. We understand that improvements in design and lubricants have eliminated the difficulty. The principal advantage of lubricated cocks is the elimination of packing problems.

Pumps

Cast-steel centrifugal pumps with steel impellers have given good service with the exception of packing difficulties. Packing problems on this pump have been greatly reduced by the use of liquid-hydrocarbon pressure-seal glands, but this application is not always permissible due to acid contamination.

Small positive-displacement-type pumps constructed of steel, Monel or special bronze have given good service; they are inexpensive, and we have found them more trouble-free for our operations than the centrifugal pump.

Packing

Obtaining suitable packing for pumps and valves and sheet packing for flanges is one of the most difficult problems encountered in handling anhydrous hydrofluoric acid. However, packing manufacturers are developing improved packings and this difficulty is apparently being solved.

The ideal pump packing should be resistant to the acid, have compressibility and should not score the shaft. Resistance to the acid is obtained by use of copper or aluminum foil, or copper metallic braid. Compressibility is obtained by the use of heavily graphited and lubricated asbestos, Neoprene or Koroseal cores, which have been moderately successful. Packing having a braided copper covering with a heavily graphited asbestos center, has been used with reasonable success for packing pumps and valves. We understand that a copper foil packing, with some of the rings containing a Neoprene or Koroseal core, is satisfactory for both valves and pumps. It is to be expected that pumps and valves packed with the best available materials will require regular inspection and removal of packing at intervals. Packing deteriorates at a higher rate on idle pumps and packing life can be conserved by starting up the pumps several times each shift. On larger valves with deep packing glands, lubrication supplied through a lantern in the center of the gland is desirable to prolong the life of the packing.

Neoprene- or Vistanex-impregnated asbestos sheet has been successful for flange packing. We would not expect a flange joint gasket of this kind to be as satisfactory as metal gaskets. Tygon has shown promise in preliminary tests and may prove superior to impregnated-asbestos sheet.

Recommendations on Construction

Welded joints are ideal for anhydrous hydrofluoric acid and welding should be used wherever possible in the construction and erection of equipment, and should be used to seal threaded joints on small lines. Welds must be full, homogeneous and free of inclusions of slag and oxides. We have found a reverse polarity welding rod of the same composition as the material being welded desirable. Good welding requires good craftsmanship and it is desirable to specify ASME Class III minimum welders.

Avoid overhead lines and slope acid lines to storage or drain tanks wherever possible. If pockets in acid transfer lines are unavoidable, methods of draining must be provided.

It is best practice to install valves below eye level with the packing glands vertical. The use of double valves is often indicated, and, in the case of globe valves, it simplifies repacking. Valves and pumps should be readily accessible, avoiding location in pits and areas congested with equipment. The repair of this equipment is not simple and may be greatly facilitated by proper placement. Open areas allow men to work on the windward side.

Wire for motors should be run in conduit and connections to motors made in flexible metal conduit.

Glass is very readily attacked by hydrofluoric acid fumes and will cloud up very quickly. Although plastic (polystyrene) is not perfectly resistant to hydrofluoric acid over a period of time, it is superior to glass and is satisfactory as a substitute for glass in gauges and instruments.

After construction has been completed all lines should be pressure tested for leaks before operation begins.

Safety Practices

As the safe handling of anhydrous hydrofluoric acid is essential to successful plant operation a study of safety practices is well worth consideration. Our experiences clearly indicate that it can be handled safely. The refining industry, long accustomed to handling hazardous materials, should solve its anhydrous hydrofluoric acid safety problems without undue difficulty.

Although safe handling of any dangerous chemical is largely the function of materials of construction and design, the human element also plays an important part. The selection of personnel should be based on ability to follow orders and obey safety instructions. The men should think straight and act quickly in cases of emergency. They should respect the material they are to handle, but they must not be afraid of it. A man who is afraid of his work is a liability and should be transferred; otherwise he may some day be responsible for injury to himself or others. It should be clearly recognized that certain men are unsuited for work with anhydrous hydrofluoric acid due to the fact that even slight concentrations of fumes will cause severe nasal and throat irritation. People who sunburn readily usually burn easily from the fumes of anhydrous hydrofluoric acid and when

working where these fumes are apt to be encountered should wear proper protective clothing. Our operators have found that zinc oxide powder applied to exposed skin surfaces minimizes the danger of burning. A special hydrofluoric acid ointment containing magnesium oxide may also be used for this purpose.

In the safe handling of anhydrous hydrofluoric acid, periodic inspection of premises and equipment, including tools and safety appliances is imperative. Regular inspection of acid lines, valves, pumps and equipment will detect leaks at their beginning, spot potential trouble and avoid costly repairs and injury. It is wise to make sure that tools and safety equipment used by the men are in good order and adequate. Repairmen should be thoroughly familiar with the anhydrous hydrofluoric acid equipment in use and with methods of repairing it. They should also be familiar with the required use of safety equipment for each job. These men must be reliable and must adhere to prescribed safety rules. Remember always that the safe handling of any dangerous chemical depends upon keeping it confined and off the skin, and all safety practices should be devised with these goals in mind.

All equipment scheduled for repair should be considered full of acid until it has been definitely established as empty. Tanks, pumps, lines and valves that are to be repaired should first be drained, flushed and evacuated. Workmen should never be allowed to attempt repair of equipment while pumps are in operation and the lines full of acid. If pipe sections are to be removed and flanges opened, the lower bolts should be loosened first and, although the lines may have been flushed, care should be taken to avoid any drip. Graphite on threads facilitates removal.

Workers should be instructed never to stand in front of an open acid line or in front of a valve while it is being opened.

If it is necessary to remove sections of lines by cutting with a torch, be doubly sure that the lines have been drained, flushed and evacuated before starting work. Operators engaged in this type of repair work where spatter is possible should wear full protective clothing. The hazard of hydrogen explosion is prevalent when cutting into empty acid lines or empty acid tanks, especially if they contained weak acid. This hazard can be minimized by adding dry ice to the receptacle or line before starting repair work. Anhydrous hydrofluoric acid is not in itself an explosive.

Equipment, such as valves, motors or fittings, removed from acid service should be identified with a distinctive marking and thoroughly washed with an alkaline solution before being handled. All workmen should know the meaning of this marking and should never touch articles of this type with bare hands or without proper protective clothing. We have found that failure to obey this rule is a cause of minor burns.

Each repairman for anhydrous hydrofluoric acid equipment should be provided with a complete set of tools and should never allow other workmen to handle them. These may at some time be contaminated with acid and men not properly protected with gloves or clothing may be burned. Tools used in acid repair service should be thoroughly neutralized with a solution of soda ash after each use. An effective way to prevent rusting is to dip them in kerosine after washing.

Workers should make a practice of never unduly exposing the skin when working in the acid section and should wear full coverage of clothing at all times. Working bareheaded, with shirt sleeves rolled up or in a undershirt is exceedingly hazardous in an acid plant. Neoprene-soled shoes or rubbers, a hat or protective head covering, face mask or goggles and Neoprene gauntlet-type gloves are indicated at all times. In addition a Neoprene-coated apron is advisable and a complete Neoprene-coated suit should be worn when repairing anhydrous hydrofluoric acid equipment. Our workmen prefer the medium weight gauntlet-type glove to the thin glove. The thin glove offers greater freedom but tears more readily and has been the cause of minor burns. Neoprene gloves should be thoroughly washed, inside and outside, and pressure tested for leaks before use. The habit of removing or raising goggles with soiled gloves should be cautioned against as it is often the cause of burns. We have found the use of a portable blower or fan helpful in whisking away fumes when tightening packing glands on valves.

Acid spilled on the floor must be neutralized immediately with soda ash. Contaminated clothing should be neutralized with bicarbonate of soda and laundered before reuse. Porous materials, such as wood and pipe coverings or packing materials, contaminated with acid should be disposed of by burning or burial.

Service lockers should be supplied for each operator in which to keep equipment used daily and it should be the duty of the foremen to see that this equipment is properly maintained and that replacements are made when necessary. A sink with ample water supply should be provided for cleaning and washing tools. We have found a bottle of Universal Wide Range Indicator very helpful for determining the presence of hydrofluoric acid on garments or tools and it can be used to advantage by the inspector to determine if the rule relative to the washing of equipment and tools is being executed. Automatic safety showers should be located near pump houses or areas where maximum repairs may be indicated. These showers must be connected to a plentiful supply of tepid water, and the type of shower which automatically operates an alarm when occupied is preferable. Prompt aid is essential in cases of burns from anhydrous hydrofluoric acid and the alarm system will indicate that a man needs aid.

You should remember that, while it is necessary to make rules, it is equally necessary to see that they are carefully followed.

First Aid

These comments on first aid are based on our experience and the experience of others in handling anhydrous hydrofluoric acid. In all cases of injury call a physician familiar with the treatment of hydrofluoric acid burns and use these suggestions only as a means of reducing injury to human beings or mitigating suffering while waiting for the doctor's arrival.

It might be well to preface these remarks on first aid with the old proverb, "An ounce of prevention is worth a pound of cure." A program based on this proverb will not only reduce human suffering but be of immense value to a growing industry. Such a program must be started early because it is based on the following fundamentals:

Equipment design and installation; Careful inspection and thorough maintenance, and formulation and strict observance of adequate safety rules.

The three important fundamental steps in first aid

for anhydrous hydrofluoric acid burns are promptness; prolonged and thorough flushing with water, and treatment for shock.

Anhydrous hydrofluoric acid attacks tissue rapidly and it is important that first-aid treatment be given immediately. If a workman is burned with anhydrous hydrofluoric acid, properly trained first-aid crews should be called instantly and respond without delay.

In adition to reacting immediately with the tissue, anhydrous hydrofluoric acid will continue to destroy tissue until it has been removed. The most effective first-aid measure is the application of large quantities of tepid water. This will flush the hydrofluoric acid from contaminated clothing as well as from the skin and will reduce injury. The treatment we use for anhydrous hydrofluoric acid burns depends upon the removal of the acid from the tissues by prolonged soaking in water, and several severe burns which we experienced responded excellently to this treatment and recovered fully. The skin after contact with anhydrous hydrofluoric acid has a peculiar marble-white appearance. After prolonged washing with water and removal of the acid the burned area will assume a natural pinkish color and this is an indication that sufficient flushing has been given. We have found that it is necessary to apply the water for a period of 3 to 5 hours for average burns, and in the case of a very severe burn, water was applied after hospitalization for a total period of nearly 12 hours. Due to the necessity of treating for shock and keeping the patient in a prone position, the water should be applied to the burned area through spray nozzles after the first initial shower flush of 5 to 10 minutes, preferably longer if shock is not too severe.

Some authorities state that they have obtained excellent results by the application of a water flush followed by alternate flushing with weak ammonia and water. Others apply a special hydrofluoric acid burn ointment, containing magnesium oxide, after the flushing period. Another method reported to be successful is the subcutaneous injection of calcium gluconate solution to precipitate the fluorine ion in an insoluble form. The whole treatment for hydrofluoric acid burns is designed to counteract the double action of the acid: the acid action, and the fluorine ion action. It is stated that the fluorine ion must be removed from the tissue to prevent deep-seated, slow-healing sores and it is a matter of opinion as to which method will accomplish this best. At least the methods are all similar in that they require copious flushing with water and if this rule is followed the first-aid crew cannot go wrong.

Pain is not experienced immediately on contact with the acid and in some cases does not occur until several hours later. Thus, workmen may receive burns and go home at the end of their shift without knowing that they have been burned. If they are not familiar with proper treatment they may use home remedies. We have had several cases of very stubborn, hard-to-heal burns following the application of grease or oil-base home remedies to the burned area without thorough flushing. Burns under the fingernails come in this classification and may result from long exposure to strong fumes, sometimes experienced by laboratory workers, or from improperly washed or defective gloves. Soaking the burned hand in a basin of cold water for a long period usually will give relief and the patient may even receive a full night's sleep by placing the basin alongside the bed. The writer has personally used this method successfully. If these burns are not quickly recognized and soaked in water they may require removal of the nail and prolonged treatment. The calcium gluconate injection may have promise as an alternative method to removal of the nail.

Small concentrations of hydrofluoric acid fumes in the atmosphere are easily recognized and usually cause coughing and irritation of the throat. Prolonged exposure to heavy concentrations may cause lung inflamation. We have never experienced any serious accidents due to burns from fumes and can only conceive of an accident of this type happening due to the operator being trapped or becoming unconscious in a heavily contaminated area. Fresh air, rest, treatment for shock, including prone position, reassurance and, in the case of stoppage of breathing, artificial respiration would be naturally indicated pending the arrival of the physician. Workmen entering areas heavily contaminated with fumes should wear full protective clothing, including supplied-air hood-type mask.

Skin burns, resulting in a reddening and soreness of the exposed skin area, sometimes occur from hydrofluoric acid fumes and people who sunburn readily are more susceptible than others to burning of the skin. Thorough flushing of the reddened skin area with water, followed by the application of a special soothing alkaline cream will relieve the discomfort. Many of our workmen have formed the habit of heavily applying zinc oxide powder to exposed skin surfaces when working in acid areas and have found it beneficial. We have information that a special protective cream containing magnesium oxide is also very effective for this purpose.

Eye burns are usually the result of a direct splash of acid in the eye and may be avoided if proper protective equipment, such as goggles, mask or face shield, is used as indicated by the safety rules. In case of an actual splash of acid in the eye, the eye should be immediately flushed with large quantities of water. Due to the clamping shut of the eyelids from involuntary muscular action, it is sometimes necessary to forcibly hold the eye open to apply the water. A bubbler fountain is ideal for flushing the injured eye. After the eye has been thoroughly washed, normal saline solution may be applied, but in all cases of eye burns it is good practice to have the man examined by a competent physician specializing in treatment of the eyes. Although fumes from hydrofluoric acid may cause the eyes to water, actual burns from moderate exposure to the fumes are rare. The copious flow of tears has a beneficial effect in that it tends to dilute and wash away the acid.

Both preventive measures and first aid can be effectively applied in the acid plant. In the period of two years in which we were pioneering in the production of this new chemical, and during which time we produced approximately a million pounds of anhydrous hydrofluoric acid, we had only two severe burns, one requiring extended medical attention and the other prolonged hospitalization. No accidents other than minor burns requiring first-aid treatment have occurred since. We suffered no fatalities due to results of anhydrous hydrofluoric acid burns and no permanent disability resulted in any of the accident cases. We feel that an analysis of accidents with subsequent adoption of corrective measures was largely responsible for this record.

Tube Cleaners—Their Application and Maintenance

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TUBE cleaners are maintenance tools, and as such they are expendable. It is necessary that stills be kept on the line producing oil and gasoline, for the downtime of refinery units represents not only a dead loss in vital war materials but an additional expense in labor. Time is all-important to most refineries and it is sometimes considered sound economics to forget tube-cleaner expense in favor of time. However, tube-cleaner manufacturers have made considerable progress in the past few years and new equipment made from new materials has not only reduced cleaning time but also maintenance costs.

Tube-cleaner manufacturers cannot be entirely responsible for the correct use and care of their equipment once it is in the user's hands. But they can offer suggestions and are very willing to make their experience available to all refineries. Unfortunately the conditions under which cleaners must operate vary widely. No two refineries have the same type and thickness of coke to remove and even the same refinery seldom has two cleanouts exactly the same. Therefore, each cleanout is an individual problem which must be solved when a still is opened. For the most part refinery operators have solved cleanout problems as they come up, but perhaps their solutions could be improved upon both with respect to speed and cost. Tube-cleaner manufacturers maintain offices and field engineers in all larger cities and their services are available at no cost to any refinery. By attending a cleanout a tube-cleaner specialist can either offer recommendations or approve cleaning and maintenance methods.

This article cannot possibly go into detail concerning all the cleaning equipment and methods in use, since what may be successful procedure in one refinery will not necessarily work out the same way in another plant. Therefore, this is offered as a general discussion in the hope that some refineries can pick out some useful information. This article will be devoted entirely to the discussion of cleaning straight still tubes and in order not to cloud the issue, cleaning curved tubes, heat exchangers and catalyst units will not be considered.

Supply Lines

Practically all refinery cleaners are air-driven although some are steam-driven. Therefore, it seems logical to start an investigation at the source of power, or at the compressors. Assuming the compressors are in good operating condition, it will require very little time to check the maximum air volume required through each air line against the pressure drop. For example, a 2-inch air line 1000 feet long with 100 pounds pressure at the compressor end will have a pressure drop of approximately 9.95 pounds while passing 300 cubic feet a minute, and if the pressure is raised to 125 pounds the drop will only be 8.18 pounds. Any handbook will supply data for your condition, but it must be remembered that numerous valves, elbows, and leaky connections increase the pressure drop. Undoubtedly some pressure drop can be eliminated by streamlining the air lines, removing old lines in use, and correcting leaky valves.

It is a very simple matter to put a pressure gage on the air supply line at the still platform and check the actual pressure drop. A medium-size motor requires 150 cubic feet a minute when 80-pounds pressure is supplied at the motor. Motors are all designed to operate at their maximum efficiency when supplied with 80-pounds pressure at the motor. Therefore, reducing the pressure drop will pay in many cases. It is also preferable to reduce the number of cleaners operating on one supply line, thus increasing the pressure to the remaining motors. A motor operating at low air pressure will not be effective in hard coke and will require more time to clean a tube while the maintenance will be practically the same.

Some refineries have found it well worth while to install traps in lines of any length to remove the moisture which is bound to accumulate. Water will not only sludge the lubricating oil usually used for cleaners but will also promote rust. Any air line should be thoroughly blown out before attaching the hose, but water will accumulate anyway in low sections of the line unless trapped off.

Hose and Couplings

Tube-cleaner hose not only provides a medium of supplying air to the cleaner but it is also the operator's means of controlling the cleaner. Therefore, the hose is just as important as the cleaner itself and should be carefully checked often. Every tube cleaner requires a certain size hose, as obviously ¾-inch hose will not pass enough air to drive a large motor, and 1-inch hose will be too large for smaller cleaners.

Cleaners for 2¾-inch straight still tubes and larger should be supplied with 1-inch hose and most refineries have found it wise to insist upon 6-ply hose, with 8-ply hose for tubes 5-inches and larger. Make sure the duck is at least 16-ounces. The hose should be wire-wound to provide protection for the rubber covering and to reduce the drag of the hose on the tube wall. The winding should be left-hand wound

so the winding will tighten against the torque of the motor. Since lubrication in most refineries is provided by introducing oil into the air lines, the hose should have an inner oil-resistant lining. The hose should be limber enough to coil easily and at the same time rigid enough so that the torque of the motor will not cause the hose to twist or knot.

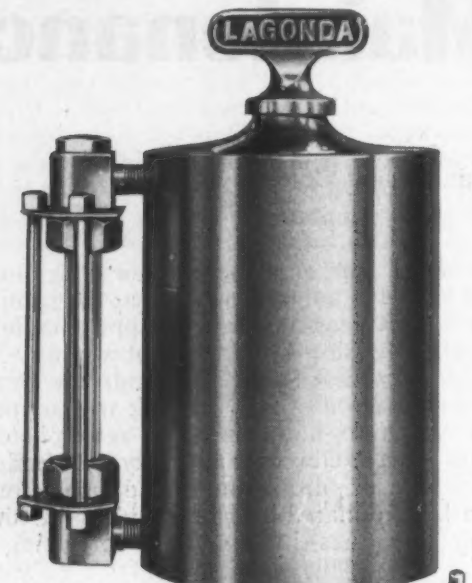


FIGURE 1
Sight-feed lubricator

Hose couplings are frequently a source of trouble and in a great many instances it is due to the hose becoming oil soaked at the motor coupling end, allowing the coupling to pull loose. Approved couplings can be and should be tightened after each cleanout. When hose shows signs of becoming oil soaked at the motor end, about a foot of the hose should be cut off and the coupling again attached. At the same time the new cross section of the hose should be carefully examined to make sure that the hose has not swollen. One refinery had in use several lengths of hose that were in excellent shape as far as the exterior was concerned, although they had been in service for some time. They were tested for pressure drop and it was found that there was about 40 pounds drop through a 50-foot length of 1-inch hose. A cross-section of the hose revealed that it had swollen to such an extent that there was only about ½-inch opening. A frequent pressure drop test will give almost the complete story on hose, keeping in mind that a 50-foot length of 1-inch new hose will have a little over 8 pounds drop when passing 150 cubic feet of air at 80-pounds pressure.

Another source of coupling trouble is with the nipple on the motor end of the hose coupling. Not many operators use a wrench to put the motor on the hose and it must be remembered that the coupling is subject to considerable vibration. If the motor is not threaded all the way on the hose nipple only a couple of threads will be holding the motor and the nipple will snap easily. Use only approved couplings with heavy nipples.

Be sure the air line is blown clear before attaching the hose and then blow the hose out before connecting the cleaner motor. Any dirt or pipe scale from the lines carried into the motor will cause trouble. When the cleanout is finished, blow the hose out again, making sure the lubricator is shut off and then coil and lay the hose flat in a cool dry place so that it will not deteriorate too rapidly.

Lubrication

Tube cleaners are lubricated by introducing oil into the air stream to the motor. There are several methods of accomplishing this but the method most widely used is a sight-feed lubricator. A typical sight-feed lubricator is shown in Figure 1. It is installed on the supply line at the inlet end of the hose. This lubricator is not automatic and the oil must be shut off when the cleaner is not in use or the oil continues to drip into the hose, with the result that the hose becomes oil soaked in time.

A tandem lubricator, such as shown in Figure 2, is less widely used. It makes the lubricator an integral part of the cleaner, thus eliminating the objection of oil in the hose. The disadvantages of this method are that the lubricator adds weight and length to the cleaner and there is no way of telling when the lubricator is empty. Furthermore, the diameter of the tandem lubricator must be smaller than that of the motor, thus it cannot be used on small motors. In fact a tandem lubricator for a motor for 3-inch tubes will have a capacity of only ¼ pint.

Perhaps the lubricator which comes nearest to answering the objections to the tandem and sight-feed lubricators is the automatic lubricator shown in Figure 3. This lubricator feeds oil through the small oil tubing inside of the air hose directly into the motor. The lubricator is outside where it can be seen and filled easily and the oil does not come in contact with the air hose. However, since the oil tubing slightly reduces the inside diameter of the air hose, an automatic lubricator cannot be used with small cleaners or air hose under one inch.

One of the most difficult questions to answer is the one heard so often, "How much oil does a cleaner require?" This obviously depends upon the size of the cleaner and the type of oil used. An attempt has been made to answer this question by saying that 25 to 30 drops per minute of a good SAE No. 40 oil should lubricate a motor. However, the only sure test for adequate lubrication should be a film of oil on the exhaust ports of the motor after it has been run.

Ordinary lubricating oil seems to sludge when there is too much moisture in the air and numerous reports indicate that a pure mineral oil compounded with rape-seed is far superior. This oil does not become gummy or tacky and one user reports a substantial increase in power with one-third the usual amount of oil. For hot work, such as still tubes, an extra heavy oil of the same compounding is used. Whatever kind of oil is used be sure to use plenty of it as oil is cheap compared to burned-out motors.

Motors

A tube cleaner motor is a precision tool. The materials and tolerances required by manufacturers

would surprise most users. Even so, motors are built so that they are easily disassembled and repaired with interchangeable parts requiring no assembly bench labor. Obviously the manufacturers expect certain parts to wear and have made provisions for their replacement. The reader will be interested in obtaining the maximum service from

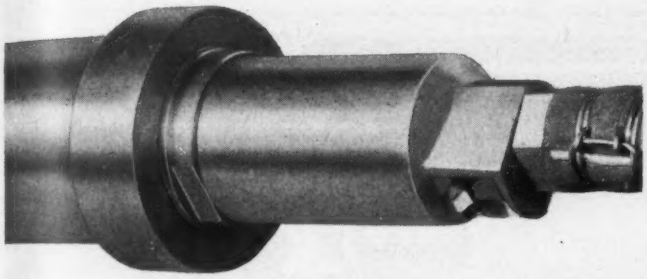


FIGURE 2
Tandem lubricator is attached directly to the tube-cleaner motor

each part and reducing the maintenance to a minimum without sacrificing the efficiency of the motor.

Motors are built for every size tube for two reasons. First, to make possible the use of as large and as powerful a motor as possible. Second, in order to fit a motor to within approximately 3/16-inch of the diameter of the tube. A slight sag in the tube may possibly stick the motor if clearance is less than 3/16-inch, but excessive breakage will be the result of too much clearance. A motor with too much clearance will literally destroy itself by vibration and in battering the tube wall. Excessive shaft breakage and front bearing wear will probably show up but the motor body will suffer most. Look for marks on the front end of the motor, and also the machine coupling loosening up due to the gradual stretching of the rear end of the body.

Construction of a motor is so simple that it is misleading. Figure 4 illustrates the Elliott 1100 series double-ball-thrust motor which was built especially for heavy-duty still cleaning. Even if the motor were running free, the air pressure would create a forward thrust on the rotor. The usual self-feeding head will pull from 40 to 60 pounds on the motor shaft. All this thrust is taken on the front thrust bearing. If the cleaner is operated in heavy coke where it is necessary to force the cleaner, the thrust is transferred to the rear bearing. Friction loss is reduced by at least 15 percent in a motor by replacing a friction thrust bearing with a ball thrust bearing. However, the greatest advantage lies in the increased efficiency since thrust clearances can be maintained at a minimum. Conventional friction thrust motors will show a noticeable decrease in power as the thrust plates become worn and air leakage increases between cylinders.

There is approximately .002-inch clearance between the air seal and the rotor. Therefore front and rear bearings must be replaced before the rotor touches the air seal and ruins the shell. A new lubrication system in the Elliott 1100 series motors provides positive lubrication under full air pressure to the front and rear bearings whereas conventional motors depend upon leakage around the thrust plates. If any oil whatsoever is being supplied to the motor, both bearings are receiving their share and the life of the motor is materially increased.

Methods of determining when repairs are necessary are many and varied. Some refineries simply use the motor until it will no longer run, while others check every part of a motor after each cleanout. Each method has its advantages and usually an experienced tube-cleaner man can tell by visual examination just what replacements are required. Probably the best method, and one used by several refineries, is to set up your own test rig and test each motor after each cleanout. A simple test rig is shown in Figure 5. By keeping a record of air consumption and torque of each motor against the serial number the need for repairs is easily discernible. A new motor will provide the basic figures to shoot at, and it will require only a few minutes after each cleanout to check the motor. If the motor pulls up somewhere near the original air consumption and torque it can simply be stored in oil until the next cleanout. If not, tear the motor down and inspect for worn parts. Be careful of the machine coupling when the motor is re-assembled. It may be pulled down tight on an 1100 series ball-thrust motor but care must be taken that the rotor is not pinched in a conventional cleaner.

Cutter Heads

Cutter heads are the most controversial subject in refinery tube cleaners and must be discussed in generalities. It has already been mentioned that no two cleanouts are exactly the same, but to give refinery engineers their due, it must be acknowledged that progress has been made in this direction. Cleanouts are fairly well scheduled these days unless something unusual has happened, the deposit in still tubes can be fairly accurately foreseen. Indications are that the thickness of the coke or scale deposit to be removed from still tubes has been gradually decreasing; few refineries now have a deposit over ¼-inch thick. But if anything the deposit is harder than ever.

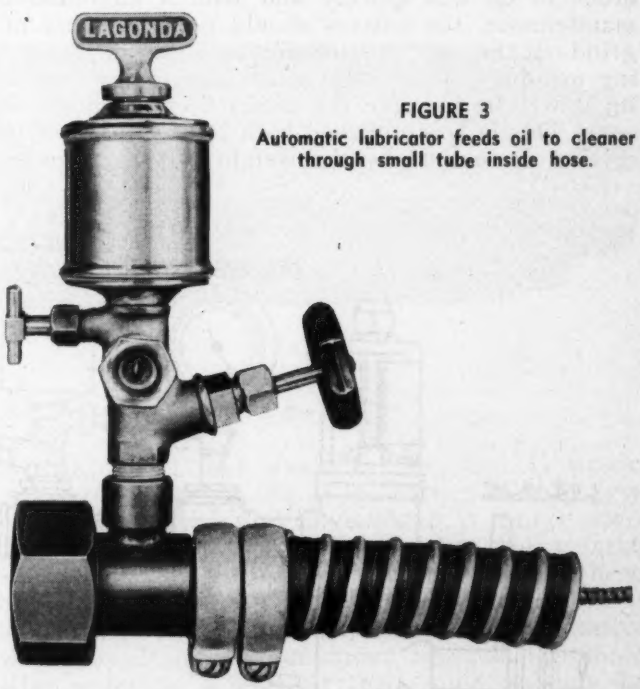


FIGURE 3
Automatic lubricator feeds oil to cleaner through small tube inside hose.

There are many cutter heads, made by various manufacturers, on the market but all of them fall into fairly definite patterns, differing only in construction details. Unfortunately there is no universal head which is adaptable for removing all types of deposit. The three basic types of heads, as made by Elliott Company, are shown in Figure 6, with (A) the "UO" head, (B) the "Clipless" head, and (C) the

"H-2" head. The "UO" head is limited to coke about ¼-inch thick; it will not always remove hard, glassy coke 1/32-inch thick. The "UO" head is built for all sizes of refinery tubes, but it is not too effective in tubes under 2½-inches in diameter. The "Clipless" head is better in small tubes and is preferred in many refineries for use in large tubes, due to its higher parts. This returns us to the old subject of air pressure as the motor must provide the necessary speed and it cannot do so unless the air pressure is 80 pounds, or higher, at the motor. However, another element creeps in, which complicates the matter. This is the fact that cutters operate part of the time on the steel tube walls and become extremely

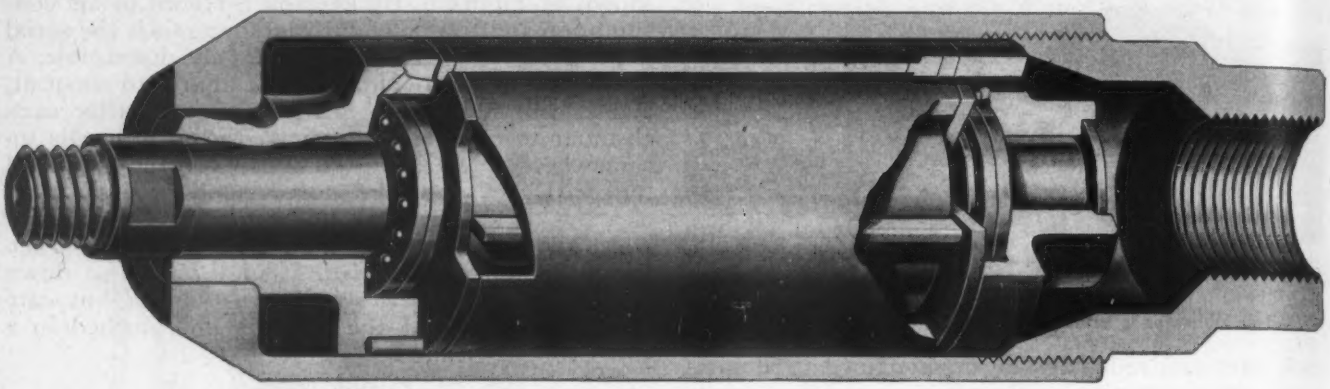


FIGURE 4
Sectional view of Elliott 1100 series double ball-thrust motor

centrifugal weight, with comparable motor speeds. The "H-2" head is an extremely vicious head with a high centrifugal weight and a small cutter surface. This head is extremely useful in very thin, hard coke, and will also remove coke slightly over ¼-inch thick. Care must be taken to keep the "H-2" head moving in the tubes as it will mark the tube wall and, in fact, it does not leave as smooth a surface as the "UO" head.

The object of any cutter head is, of course, to remove the coke deposit inside of the still tubes. In order to do this quickly and with a minimum of maintenance, the cutters should penetrate and not grind out the coke. It is readily seen that the expanding members of the head must have enough centrifugal weight to force the cutter teeth through the coke. This is accomplished both by the speed of the driving motor and by the weight of the expanding hot during operation. Above a certain peripherial speed, the cutters and pins will turn blue and lose their hardness, and are then worn down in short order. Therefore, motors and heads should be matched so the motor speed will not be above the allowable head speed.

The greatest problem in tube-cleaner work is making the correct application. As so often happens, the air pressure is already set at a given figure and

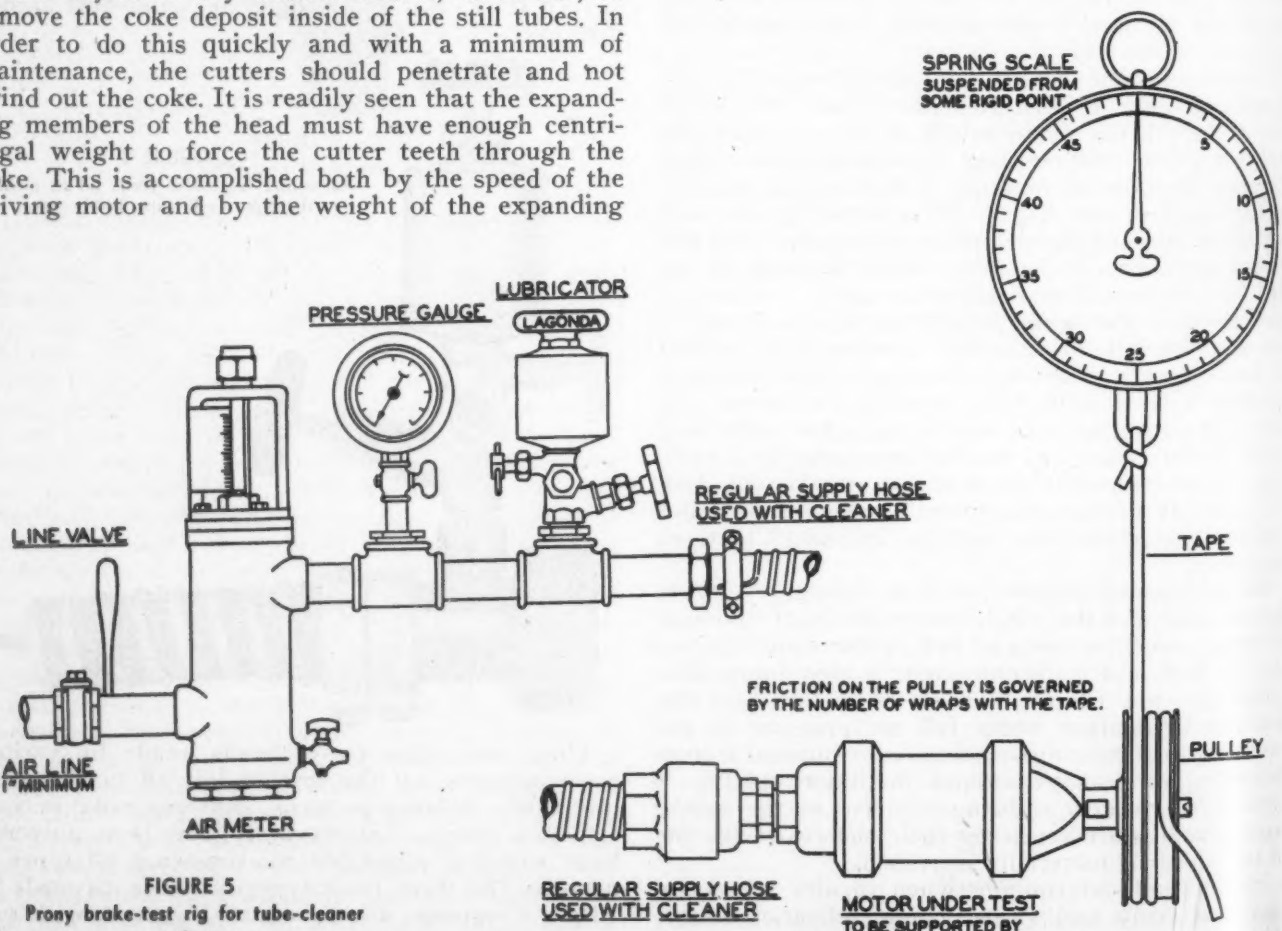


FIGURE 5
Prony brake-test rig for tube-cleaner motors.

cannot be varied. It is then up to the cutter head to do a good job with a given speed and coke condition. If air pressure is low, a "Clipless" or an "H-2" head is usually more effective than a "UO", and vice versa if the air pressure is high.

All of this of course depends upon the type of coke in which the head is operated. Many refineries have spent considerable time experimenting with various types of heads and have finally settled upon a certain type and so long as their coke remains the same and the air pressure does not vary, the head should continue to be satisfactory, but any deviation in either reduces the effectiveness of the head.

More heads have failed because of incorrect application than for any other reason. Each cutter head has a minimum and maximum throw and the head must be used in tubes in which the diameter remains somewhere in this range of throw. Perhaps the most common difficulty is because of oversize tubes. A cutter head will easily destroy itself if the cutters cannot reach the tube wall at all times. A cutter head always attempts to center itself and the motor in the tube. A cutter head obviously cannot do this if its maximum diameter is under the maximum inside diameter of the tube, and the result will be that cutters will chip, since the head will develop a vibrating and scraping action. Wear on the cutters will be noticeable within a few minutes and the vibration from the cutter head will be carried through the hose, indicating plainly to the operator that the cutter head is bouncing around in the tubes rather than allowing the cutters to roll smoothly on the inside of the tube wall.

All cutters are carefully hardened to produce as tough a cutter as possible without brittleness. It is realized that it would be very helpful to operators if a definite wear point could be established for cutters, at which point they would be discarded. However, this depends on the size of the cutters and the type of deposit in which they are working. A trained operator can establish a point where labor and material will balance. As cutters become dull, a cutter head naturally will become less effective and the speed of the cutting action will be decreased. A representative of a tube-cleaner manufacturer can tell you more after watching a cleanout than could possibly be contained in an article of this kind.

Cutter heads are so constructed that the most expensive part, namely the spider, receives very little, if any, wear. Examine the spider of your cutter closely for wear, especially on the exterior. Any indication that the spider is touching the tube wall or coke is a warning that the correct cutter head is not being used.

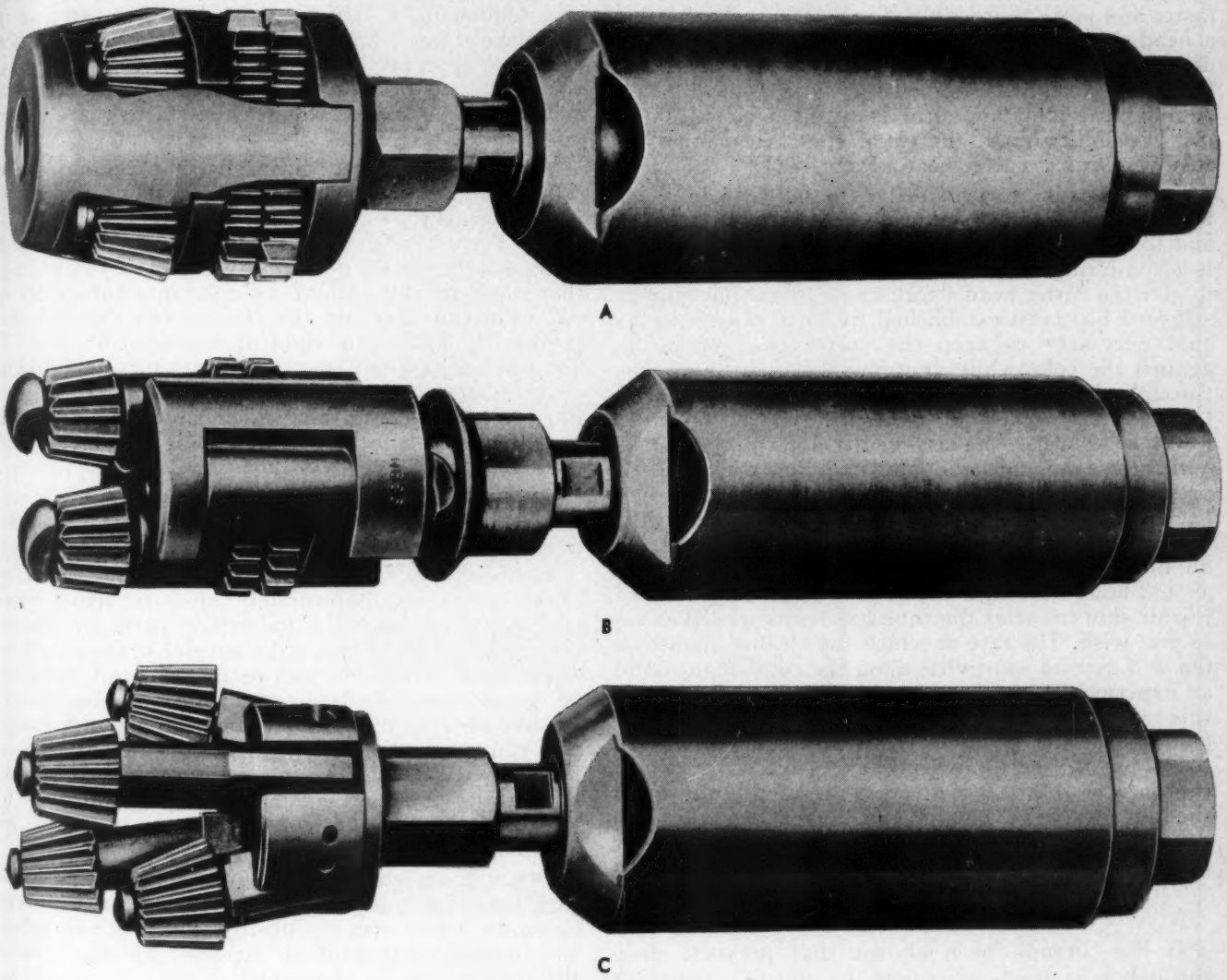


FIGURE 6
Illustrating the three basic types of heads—A the "UO," B the "Clipless," C the "H-2"

As already stated, there is no universal cutting head. It has been demonstrated in some refineries that, for a difficult cleaning job, time can be saved by making two passes through a tube using different types of cutter heads. It is common practice to use a universal joint and drill for a first pass through heavily coked tubes and then finish up with a "UO" head. It is recommended that the drill be fed through the tubes just as fast as possible in order to check and crack the coke rather than to remove it. Once this has been done, a cutter head will remove the coke faster and more thoroughly. In very light, hard coke, a head, such as the "H-2", or a universal joint and drill, could be used in the same manner to crack or check the coke, to be followed up with a "UO" head. A universal joint and drill is recommended as the last possibility only, that is if the coke cannot be removed with a cutter head of any kind.

Cutter heads are provided with self-feed in order to make sure that the head does not lie in one spot, and to make it easier for the operator. This self-feed is accomplished by setting the cutter pins at an angle to give the cutter head a corkscrew effect. The correct self-feed has been established by long experience as that necessary to keep the cutter head operating against the coke while dragging the motor and hose through the tube. In other words, it is automatic. Of course, with low air pressure and consequently lower head speed, the self-feed is not so pronounced and the cleaner must be hand fed, and when the air pressure is high, it is necessary to hold the cleaner back slightly. Do not make a practice of pulling the motor and cutter head back against the self-feed. To obtain the maximum service from cutters, the head should be fed through the tubes at a steady rate and the air shut off after the tube has been cleaned as far as you wish. The rate at which the cleaner should be fed will depend somewhat upon the coke deposit and an experienced operator should be able to determine this rate after cleaning the first two tubes. If fed too fast, the cleaner is apt to jump over coke, and if fed too slow, the result will be excessive wear. Clean thoroughly as you go to avoid re-runs. Once again the advantage of having the correct air pressure supplied to the motor is indicated, since the cutter head will then take care of its own self-feed.

Operating Suggestions

It has already been shown that pressure drop through hose tends to reduce the effective power at the motor. Many refineries have overcome part of this drop by using as short a length of hose as possible. Others have gone even farther and clean only half of a tube from each side. This pays dividends in two ways. First, it reduces the necessary length of hose, increasing the pressure to the motor, and also eliminates the necessity of handling and coiling long lengths of hose. Second, it eliminates the danger of running the cutter head out the other end of the tube and allowing the head to destroy itself. It is always necessary to set up and clean the other end of the tube anyway. For instance, instead of a 50-foot length of hose to clean a 40-foot tube, try a 30-foot length hose and clean only halfway. The hose will not tend to twist and knot as badly as a longer length and the self-feeding cutter head will not have as much weight to drag through the tube.

The Elliott Company has developed a foot valve that works like an accelerator in an automobile. A length of hose—no longer than the distance between the nearest air line connection and the farthest tube—should be used. This hose should last for quite a while since it is not subject to motor torque or tube abrasion. Be sure to keep this hose as short as possible. The foot valve gives the operator instant control of his cleaner and is an excellent safety precaution. He may clean the entrance of the tube while controlling the motor speed and instantly stop the motor if the cleaner gets out of hand. The operator may remove his foot if the valve is wide open and it will remain open but the valve automatically closes if his foot is removed while the valve is only part way open. This also eliminates the necessity of an extra man to handle the air valve while starting a cleaner in the tube.

Practically all cutter heads used in refineries are self-feeding. Let the cleaner feed slowly and evenly and if necessary hold it back slightly and the head will not jump coke. Do not work the motor back and forth as it causes excessive cutter wear. If you believe that there are still patches of coke in a tube after it has been run once, let the cleaner run through the tube fairly fast while sighting through the tube. If you can see daylight past the cleaner it is not leaving coke and the tube is clean. If the light blots out, you have run into a patch of coke. This indicates that you have fed the cleaner too fast and it should be held back slightly in the next tube.

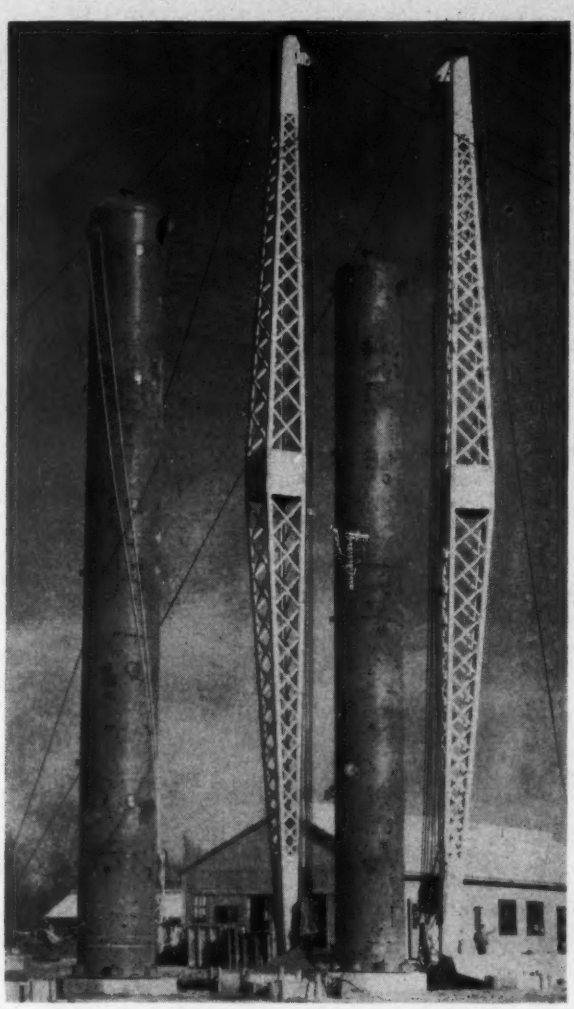
After each cleanout, test and repair your cleaner. It is satisfying to know that you are ready for the next shutdown, no matter when it comes.

Establish high and low limits for your stock of repair parts and immediately after repairing your cleaners enter an order for repair parts to replace your used parts. Do not order several years supply of repair parts. Shipment will be delayed and you may be caught with obsolete parts which will be too expensive to scrap if your coke condition should change and your present cutter head would not be suitable. Remember, tube-cleaner manufacturers are constantly working on new and better cleaners and it is to your advantage to be in a position to capitalize on modern developments.

Organize and train a tube cleaner crew and make sure that the same crew cleans tubes during every cleanout. A new man can destroy cleaners, ruin tubes, and in general, become an expense. An old hand at the job can tell by the sound of the motor and the feed of the head just how fast he can clean tubes without passing up coke. He also knows when his motor needs repair and his cutters are used up.

Install a pressure gauge on each still platform and watch the air pressure closely. Check the time required to clean a tube with 90-pounds pressure on the hose against the time required with 70-pounds pressure. When the air pressure does drop, shut down the cleaners until it has been corrected as your maintenance cost will continue as long as the cleaners run and you are not getting your money's worth out of your cleaner.

Manufacturers maintain offices in all larger cities and all men are qualified to help and advise you in your problems. Use this service. You may believe that you have no problems but it will cost absolutely nothing to ask a manufacturer's representative to be present at your next cleanout.



The Design of Foundations For Stacks and Towers

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FROM the viewpoint of the foundation designer, stacks and towers may be divided into two general classifications, depending on the method utilized to maintain them in a vertical position; (a) Self-supporting, which resist the overturning forces by the size, shape and weight of the foundation (b) Guyed, in which the overturning forces are resisted by guy wires. It is obvious that the conditions affecting the design of foundations for these two types will not be the same, and that it is necessary to treat them separately.

The same principles apply to foundation design for either stacks or towers. In the case of stacks, the brick lining is a variable load, corresponding to, and requiring the same treatment as the liquid, insulation, etc., in a tower. This discussion will

THROUGH Section 17, this article is a revision of a previous consideration under identical title in the December, 1939, issue of *Petroleum Refiner*. All copies of that issue, all reprints and all copies of the 1940 Process Handbook, in which the original article was reproduced, failed to meet the demand for this engineering data.

When the author considered the revision he extended the subject to include actual design of foundation types commonly required in the erection of refinery vessels. The result is a thorough study of a subject which continues to hold a forefront position in refinery engineering.

Reprints will be provided in quantity sufficient to satisfy the demand that has extended into construction fields outside of refining.

be based on the design of tower foundations, however, it should be kept in mind that it is also applicable to stacks.

2. Self-Supporting Tower

There are two main considerations in designing the foundation for a self-supporting tower; (a) soil loading (b) stability. The foundation must be of such size and shape that the load on the soil below will not exceed the maximum load which it will safely support. The foundation must also maintain the tower in a vertical position, so that it will not be overturned by the maximum forces acting upon it.

No direct method of calculating the size of the foundation has been developed, therefore, it must be determined by trial and error. A size is assumed, and the soil loading and stability calculated. If the results are not satisfactory, another assumption is made, and the calculations repeated.

3. Soil Loading

(See Section 20 for complete definition of terms.)

The soil loading may be determined by the following formula:

$$S = S_1 + S_2 \quad (1)$$

where

S = total unit soil loading (lbs./sq. ft.)
S_1 = unit soil loading due to dead load (lbs./sq. ft.)
S_2 = unit soil loading due to overturning movement (lbs./sq. ft.)

4. Dead Load

The dead load S_1 may be determined as follows:

$$S_1 = \frac{W}{a} \quad (2)$$

where

a = area of base of foundation (sq. ft.)
W = total weight on soil (pounds) calculated by the following equation:

$$W = W_t + W_a \quad (3)$$

W_t = Minimum dead load (pounds), which is the weight of the empty tower plus the weight of the foundation, including the earth fill on top of the base.
W_a = Weight of auxiliary material and equipment supported by the tower and foundation (pounds), which should include the liquid in the tower, insulation, platforms, piping, etc. (Does not include weight of tower)

5. Overturning Load

The overturning load S_2 is the result of the overturning moment. Under ordinary conditions, the only force tending to overturn the tower is the wind pressure.

The magnitude of the wind pressure is obviously a function of the wind velocity, which varies in different localities. In many instances laws have been enacted which state the wind velocity or wind pressure to be used for design purposes.

The United States Weather Bureau has proposed the following formula:

$$p = 0.004\frac{B}{30}V^2 \quad (4)$$

where

p = wind pressure on a flat surface (pounds/sq. ft.)
B = barometric pressure (inches H_g)
V = velocity of wind (miles per hour)

For a barometric pressure of 30 inches, the formula becomes:

$$p = 0.004V^2 \quad (5)$$

It has been found that the wind pressure on a cylindrical tower is about 60 percent of that on a flat surface. For a cylindrical tower, therefore, formula (5) becomes:

$$p_c = 0.0025V^2 \quad (6)$$

where

p_c = wind pressure on the projected area of a cylindrical tower (pounds per square foot).

In most localities, a wind velocity of 100 miles per hour is considered the maximum. This gives a pressure of 25 pounds per square foot on the projected area of the tower, which is the figure generally used for design purposes. It should be emphasized, however, that this figure is subject to variation in different localities, and that local laws should not be overlooked in this connection.

(Note: As a matter of interest, the wind pressure on an octagon shaped stack is considered to be 70 percent of that on a flat surface.)

Figure 1 represents a tower, mounted on a concrete foundation. The wind pressure (P_w) tends to rotate the tower and foundation about point A at the intersection of the vertical centerline and the base of the foundation. This rotating effect produces an overturning moment which can be calculated as follows:

$$M_f = P_w L \quad (7)$$

where

M_f = overturning moment about the base of the foundation (foot pounds)
P_w = total wind load (pounds) to be calculated as follows:

$$P_w = p_c \; D_o H \quad (8)$$

L = lever arm of wind load (feet) to be calculated as follows:

$$L = h_f + \frac{H}{2} \quad (9)$$

D_o = diameter of tower measured over insulation (feet)
H = height of tower (feet)
h_f = height of foundation (feet)

It should be noted that all dimensions are stated in feet, giving the overturning moment (M_f) in foot pounds. This avoids the use of the excessively large numbers encountered with the usual inch pound units. Care should be taken, however, to use consistent units, that is foot pounds, in all calculations.

The stress, or load, on the soil resulting from the overturning moment (M_f) varies from point to point, and the maximum load (S_2) can be calculated as follows:

$$S_2 = \frac{M_f}{Z} \quad (10)$$

where

Z = section modulus of the base of the foundation. (Note: Z to be based on dimensions in feet.)

The value of (Z) can be expressed as follows:

$$Z = \frac{I}{c} \quad (11)$$

where

I = moment of inertia of the base of the foundation (based on dimensions in feet).
c = distance from neutral axis of foundation base to point of maximum stress (feet).

Having calculated (S_1) and (S_2) as explained above, the total soil load under maximum dead

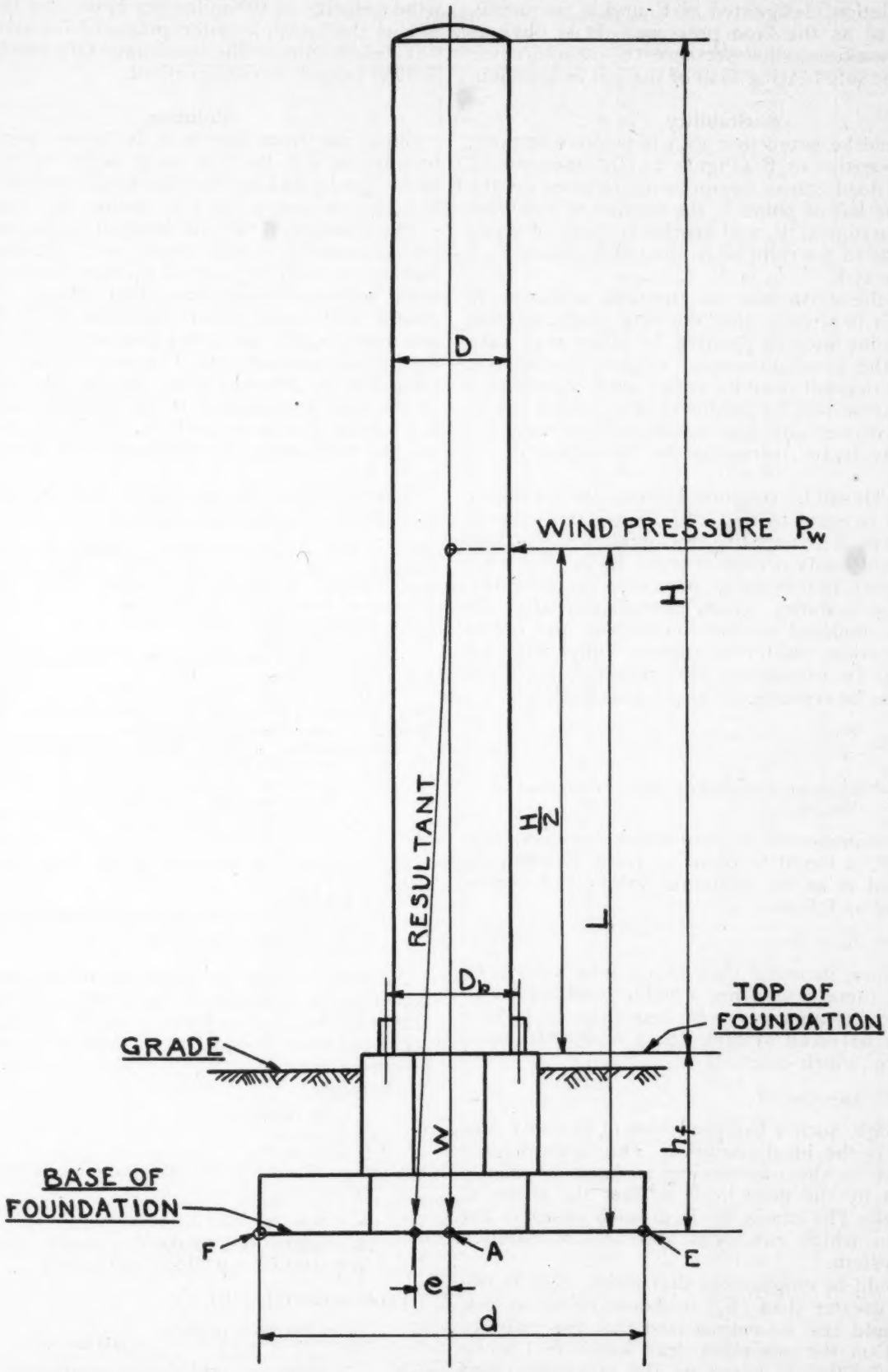

FIGURE 1
Foundation for self-supporting tower.

load conditions can be determined by equation (1).

This maximum soil load occurs at the edge of the foundation, designated as F, and is frequently referred to as the "toe pressure." It is obvious that the maximum toe pressure (S) should never exceed the safe bearing load of the soil in question.

6. Stability

It should be noted that (S_2) is positive at point F, and negative at E (Figure 1). In other words, the wind load causes compressive stresses on the soil to the left of point A, the maximum compression occurring at F, and tensile stresses of equal magnitude to the right of A, the maximum tension occurring at E.

Since the earth has no strength whatever in tension, it is obvious that the sum of the stresses at any point must be positive. In other words, the base of the foundation must exert a compressive force on the soil over its entire area, otherwise a tensile stress will be produced at E, which means that the tower and foundation will be unstable, and likely to be overturned by the action of the wind.

It was shown by equation (1) that the maximum soil load is equal to ($S_1 + S_2$). Since the value of S_2 at point E is negative, the minimum soil load (which obviously occurs at point E) is ($S_1 - S_2$).

It is very important to note that the condition of poorest stability occurs immediately after the tower is mounted on the foundation, and before the insulation, platforms, piping, liquid, etc., are in place. In calculating the stability, therefore, (S_1) must be replaced by (S_{1m}) as follows:

$$S_{1m} = \frac{W_t}{a} \qquad (2\text{-a})$$

where

S_{1m} = minimum soil loading due to dead load (lbs./sq. ft.)

The minimum soil loading which can ever exist, therefore, is found to occur at point E when the dead load is at its minimum value, and can be expressed as follows:

$$S_{min} = S_{1m} - S_2 \qquad (1\text{-a})$$

Therefore, in order that (S_{min}) may always be positive, thereby assuring a stable condition at all times, (S_{1m}) must never be less than (S_2). In a perfectly balanced system, (S_{1m}) is exactly equal to (S_2), in which case

$$S_{min} = S_{1m} - S_2 = 0 \qquad (1\text{-d})$$

Although, such a balanced system is rarely possible, it is the ideal condition. The upward force at E due to the overturning moment is exactly balanced by the dead load, so that the stress at E is zero. The stress at F in such cases is the minimum which can exist and still maintain a stable system.

It should be emphasized that while (S_{1m}) is frequently greater than (S_2) it should never be less.

It should also be emphasized that the stability is based on the minimum dead load (W_t) while the soil loading is based on the maximum dead load (W).

7. Example No. 1

Design the concrete founation for a tower 4 ft. dia. by 54 ft. high, including a 4 ft. skirt, and weighing 30,000 lbs. empty. The insulation, platforms and piping weigh 9000 lbs., the maximum wind velocity is 100 miles per hour, and the frost line at the location of the proposed installation is 4 ft. below grade. The maximum safe soil loading is 2000 pounds per square foot.

Solution

Since the frost line is 4 ft. below grade, the foundation will be 6 ft. deep, with the top 1 ft. above grade, making the bottom of the foundation 5 ft. below grade, or 1 ft. below the frost line.

The foundation will be octagon shape, which is recommended for such cases, as it combines the features of stability, ease of construction and minimum material better than other shapes. The top course will have a short diameter of 6 ft. since the tower is 4 ft. dia. and allowance must be made for foundation bolts, etc. The short diameter of the base will be assumed to be 13.5 ft. The thickness of the base will depend on the bending and shearing forces (see Sections 19 to 19h incl.), however, for the time being the thickness will be assumed to be 2 ft.

The weight of the foundation will be calculated as follows (all slide-rule figures):

Area of 6 ft. octagon $= 0.828\ d^2 = 0.828 \times 6^2 = 29.8$ sq. ft.
Volume of top course $= 4$ ft. $\times\ 29.8 = 119.2$ cu. ft.
Area of base (octagon) (a) $= 0.828 \times 13.5^2 = 151$ sq. ft.
Volume of base $= 2$ ft. $\times\ 151 = 302$ cu. ft.
Total volume $= 119.2 + 302 = 421.2$ cu. ft.
Weight of concrete $=$
421.2 cu. ft. $\times$ 150 lbs./cu. ft. $= 63{,}000$ lbs.
Volume of earth fill
(4 ft. $-$ 1 ft.) $\times$ (151 sq. ft. $-$ 29.8 sq. ft.) $= 363$ cu. ft.
Weight of earth fill $= 363$ cu. ft. $\times 90$ lbs./cu.ft. $= 32{,}700$ lbs.
Weight of empty tower $= 30{,}000$ lbs.
$W_t = 30{,}000 + 63{,}000 + 32{,}700 = 125{,}700$ lbs.
W_a will be as follows:

Insulation, platforms, piping, etc.	= 9,000 lbs.
Water required to fill the tower (4 ft. dia.) (50 ft. high)	= 39,500 lbs.
Total (W_a)	= 48,500 lbs.

$W = 125{,}700 + 48{,}500 = 174{,}200$ lbs. (from equation 3)
$a = 151$ sq. ft.

$$S_1 = \frac{174{,}200 \text{ lbs.}}{151 \text{ sq. ft.}} = 1155 \text{ lbs./sq. ft.} = \text{Maximum dead load on soil (equation 2)}$$

Allowing 3" for the thickness of the insulation, the effective diameter of the tower exposed to the action of the wind is 4.5 ft. A wind velocity of 100 miles per hour is equal to 25 pounds per sq. ft. of projected area.

Therefore:

$p_e = 25$ lbs./sq. ft.
$D_e = 4.5$ ft.
$H = 54$ ft.
$P_w = 25 \times 4.5 \times 54 = 6080$ lbs. (equation 8)
$h_f = 6$ ft.

$$L = 6 + \frac{54}{2} = 33 \text{ ft. (equation 9)}$$

$M_f = 6080 \times 33 = 200{,}000$ foot pounds (equation 7)
$Z = 0.1016\ d^3 = 0.1016 \times 13.5^3 = 248.5$

From equation (10)

$$S_2 = \frac{200{,}000 \text{ ft. pounds}}{248.5} = 803 \text{ lbs./sq. ft.} = \text{maximum soil load due to overturning moment.}$$

The total maximum soil load (toe pressure) can be calculated from equation (1) as follows:

$$S = 1155 + 803 = 1958 \text{ lbs./sq. ft.}$$

TABLE 1

Elements of Octagonal Base

Short Diameter d (Feet)	Area a (Sq. Ft.)	Length of Side (Feet)	Neutral Axis to Extreme Fiber c (Feet)	Section Modulus Z	Radius of Gyration r (Ft.)
3	7.45	1.242	1.62	2.74	0.772
3.5	10.6	1.449	1.89	4.37	0.900
4	13.2	1.656	2.16	6.50	1.029
4.5	16.8	1.863	2.43	9.23	1.158
5	20.7	2.070	2.70	12.68	1.286
5.5	25.0	2.277	2.98	16.45	1.415
6	29.8	2.484	3.25	21.90	1.542
6.5	34.8	2.691	3.51	27.90	1.67
7	40.5	2.898	3.78	34.90	1.80
7.5	46.5	3.105	4.06	42.80	1.93
8	52.8	3.312	4.33	52.00	2.06
8.5	59.5	3.519	4.59	62.70	2.17
9	66.8	3.726	4.87	74.10	2.31
9.5	74.5	3.933	5.13	87.30	2.44
10	82.8	4.140	5.41	101.60	2.57
10.5	91.2	4.347	5.67	117.60	2.70
11	100.0	4.554	5.94	135.00	2.83
11.5	109.8	4.761	6.22	154.10	2.96
12	119.5	4.968	6.48	174.50	3.09
12.5	129.2	5.175	6.76	198.00	3.22
13	140.0	5.382	7.03	221.00	3.34
13.5	151.0	5.589	7.30	248.50	3.47
14	162.0	5.796	7.57	277.00	3.60
14.5	174	6.003	7.83	309.20	3.73
15	186	6.210	8.11	342.00	3.86
15.5	199	6.417	8.38	375.00	3.99
16	212	6.624	8.65	416.00	4.12
16.5	226	6.831	9.02	455.00	4.24
17	240	7.038	9.19	497.00	4.37
17.5	253	7.245	9.46	543.00	4.50
18	268	7.452	9.72	590.00	4.63
18.5	283	7.659	10.00	624.00	4.76
19	299	7.866	10.25	652.00	4.89
19.5	315	8.073	10.55	731.00	5.02
20	332	8.280	10.81	811.00	5.14
20.5	348	8.487	11.08	873.00	5.27
21	365	8.694	11.35	933.00	5.40
21.5	383	8.901	11.62	1005.00	5.53
22	401	9.108	11.90	1085.00	5.66
22.5	420	9.315	12.17	1145.00	5.78
23	438	9.522	12.43	1240.00	5.92
23.5	458	9.729	12.71	1320.00	6.04
24	477	9.936	12.98	1400.00	6.17
24.5	497	10.143	13.25	1490.00	6.29
25	518	10.350	13.52	1585.00	6.43
25.5	539	10.557	13.79	1685.00	6.56
26	560	10.764	14.07	1787.00	6.68
26.5	582	10.971	14.33	1900.00	6.82
27	603	11.178	14.61	2010.00	6.94
27.5	526	11.385	14.88	2110.00	7.07
28	650	11.592	15.15	2220.00	7.20
28.5	672	11.799	15.42	2350.00	7.33
29	695	12.006	15.68	2470.00	7.46
29.5	720	12.213	15.96	2600.00	7.58
30	745	12.420	16.23	2740.00	7.71
31	795	12.834	16.77	3021.00	7.97
32	848	13.248	17.31	3330.00	8.23
33	902	13.662	17.85	3660.00	8.48
34	958	14.076	18.38	3980.00	8.75
35	1015	14.490	18.92	4370.00	9.00
36	1075	14.904	19.47	4730.00	9.26
37	1134	15.318	20.01	5130.00	9.51
38	1195	15.732	20.55	5580.00	9.77
39	1260	16.146	21.09	6020.00	10.04
40	1325	16.560	21.65	6500.00	10.28

This loading is satisfactory, as the soil will safely support 2000 lbs./sq. ft.

From equation (2-a)

$$S_{1m} = \frac{125{,}700 \text{ lbs.}}{151} = 830 \text{ lbs./sq. ft.}$$

This is the dead load under the worst stability condition, and since it is greater than the overturning stress ($S_2 = 803$), the soil below the foundation will always be under compression at all points, thus indicating that the foundation is stable.

Usually it is found that the first assumption as to foundation size is not correct, in which case, another assumption is made, and the calculations repeated.

It is interesting to note that the soil loading of 2000 lbs./sq. ft. allowed in this problem is rather low, as good clay soil will usually support about 4000 lbs./sq. ft. Care should always be taken, to ascertain the actual load carrying value of the soil at the site of construction.

8. Eccentricity

It will be noted that there are two forces acting on foundations of the type under consideration; (a) The dead load, acting in a vertical direction; (b) the wind load, acting in a horizontal direction. The combined action of these two forces, that is, their resultant, has the same effect as an eccentric vertical load. As explained previously, it is not necessary to calculate the eccentricity in order to determine the stability of the foundation. Several methods have been proposed, however, which make use of the eccentricity, and since there are definite relationships between eccentricity and stability, they will be explained as a matter of interest.

The eccentricity can be calculated as follows:

$$e = \frac{M_f}{W_t} \tag{12}$$

where e = eccentricity (feet)

Note: The value of (e) calculated by equation (12) is the maximum value, as the dead load (W_t) is minimum. The eccentricity for other conditions of dead loading may be obtained by substituting the proper weight in place of (W_t).

It has been shown by previous discussion that the following relationships exist:

$$S_{1m} = \frac{W_t}{a} \tag{2-a}$$

$$S_2 = \frac{M_f}{Z} \tag{10}$$

$$Z = \frac{I}{c} \tag{11}$$

combining equations (10) and (11)

$$S_2 = \frac{M_f c}{I} \tag{13}$$

rearranging equation (12)

$$M_f = W_t e \tag{12a}$$

combining equations (12a) and 13)

$$S_2 = \frac{W_t e c}{I} \tag{14}$$

It was shown by equation (1-a) that in order to avoid tensile stress at E (which would make the foundation unstable), the maximum value of (S_2) is as follows:

$$S_2 = S_{1m} \tag{15}$$

thus making the value of (S_{min}) equal to zero, as shown by equation (1-d).

Substituting the values obtained by equations (2-a) and (14) in equation (15)

$$\frac{W_t e c}{I} = \frac{W_t}{a} \tag{16}$$

The value of I can be expressed as follows:

$$I = ar^3 \tag{17}$$

where r = radius of gyration of base (feet)

substituting in equation (16)

$$\frac{W_t e c}{ar^3} = \frac{W_t}{a} \tag{18}$$

Hence, the maximum value of (e) for stable conditions is

$$e_{max} = \frac{r^3}{c} \tag{19}$$

In the case of a circular foundation

$$c = \frac{d}{2} \tag{20}$$

Substituting in equation (19)

$$e_{max} = \frac{2r^3}{d} \tag{21}$$

Substituting the value of (r^2) in equation (21), the maximum value of (e) for a circular base is $\left(\frac{d}{8}\right)$, thus confirming the common rule that in a stable foundation the resultant must fall within the middle-quarter of the diameter of a circular base.

In the case of the octagon base usually used for tower foundations, the maximum allowable eccentricity becomes

$$e_{max} = 0.122\,d \tag{22}$$

The area surrounding the center of the base, within which the resultant causes a compressive stress over the entire base, is known as the kernel or kern.

It follows, then, that the resultant must always fall within the kern of the base in order to assure stability.

In example No. 1 (Section 7), it was shown that the foundation is stable, since the overturning stress (S_2) is less than the minimum dead load stress (S_{min}).

The stability of this foundation will now be calculated (as example No. 2) on the basis of the eccentricity for the purpose of comparing the two methods.

From equation (12) the eccentricity is

$$e = \frac{M_f}{W_t} = \frac{200{,}000 \text{ foot pounds}}{125{,}700 \text{ lbs.}} = 1.59 \text{ ft.}$$

From equation (22), the maximum permissible eccentricity is

$$e_{max} = 0.122d = 0.122 \times 13.5 = 1.64 \text{ ft.}$$

Inasmuch as the actual eccentricity (1.59) is less than the maximum permissible eccentricity (1.64) the foundation is stable, thus confirming the conclusion reached in Section 7.

9. Method of Calculating Soil Load From Eccentricity

It is possible to calculate the soil loading (toe pressure) as a function of the eccentricity. This method will be explained in order that it may be compared with the method described in Sections 3, 4 and 5.

Let (k) be a factor by which the dead load pressure must be multiplied to equal the soil loading due to overturning as follows:

$$kS_1 = S_2 \tag{57}$$

Substituting in equation (1)

$$S = S_1 + kS_1 \tag{58}$$

or

$$S = S_1 (1 + k) \tag{59}$$

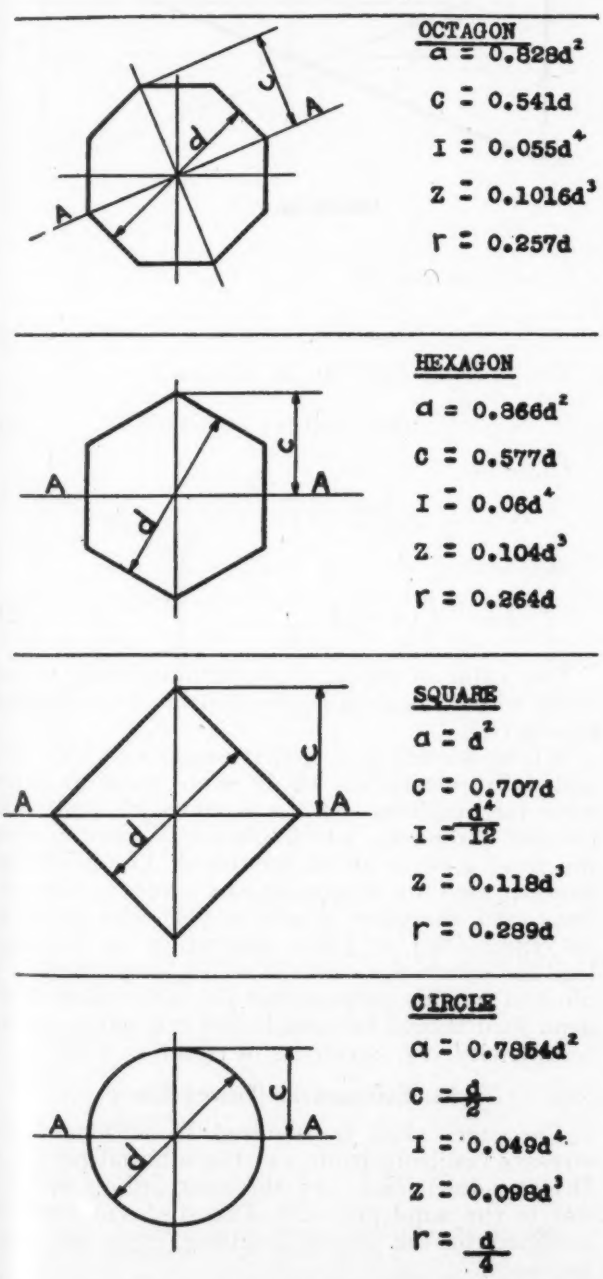

FIGURE 2
Elements of foundation bases (Axis A-A)

From equation (2)

$$S_1 = \frac{W}{a} \tag{2}$$

From equation (10)

$$S_2 = \frac{M_t}{Z} \tag{10}$$

therefore

$$M_t = S_2 Z \tag{60}$$

Substituting the value of (S_2) from equation (57)

$$M_t = S_1 kZ \tag{61}$$

therefore

$$S_1 = \frac{M_t}{kZ} \tag{62}$$

From equations (2) and (62)

$$S_1 = \frac{W}{a} = \frac{M_t}{kZ} \tag{63}$$

and

$$M_t = \frac{WkZ}{a} \tag{64}$$

From equation (12)

$$e = \frac{M_t}{W_t} \tag{12}$$

The value of (e) calculated from equation (12) is maximum for any particular foundation, which is the value governing stability. At the present moment we are concerned with the maximum soil loading (toe pressure) which occurs when the dead load is maximum. It is therefore necessary to substitute (W) in place of (W_t) as follows:

$$e = \frac{M_t}{W} \tag{65}$$

Equation (64) can be written

$$\frac{M_t}{W} = \frac{kZ}{a} \tag{66}$$

Since the term $\left(\frac{M_t}{W}\right)$ occurs in both equations (65) and (66), it follows that

$$e = \frac{kZ}{a} \tag{67}$$

and

$$k = \frac{ea}{Z} \tag{68}$$

Substituting this value of (k) in equation (59)

$$S = S_1 \left(1 + \frac{ea}{Z}\right) \tag{69}$$

In the case of an octagonal base,

$$a = 0.828\ d^2 \tag{70}$$

$$Z = 0.01016\ d^3 \tag{71}$$

Substituting these values in equation (68)

$$k_{octagon} = \frac{8.15e}{d} \tag{72}$$

Therefore, for an octagonal base, equation (69) may be written:

$$S_{octagon} = S_1 \left(1 + \frac{8.15e}{d}\right) \tag{73}$$

For comparison, the maximum soil loading in

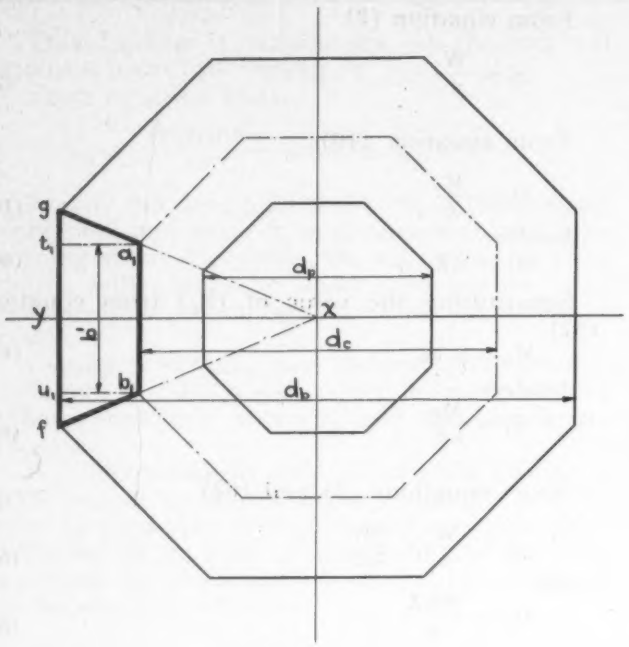

FIGURE 3

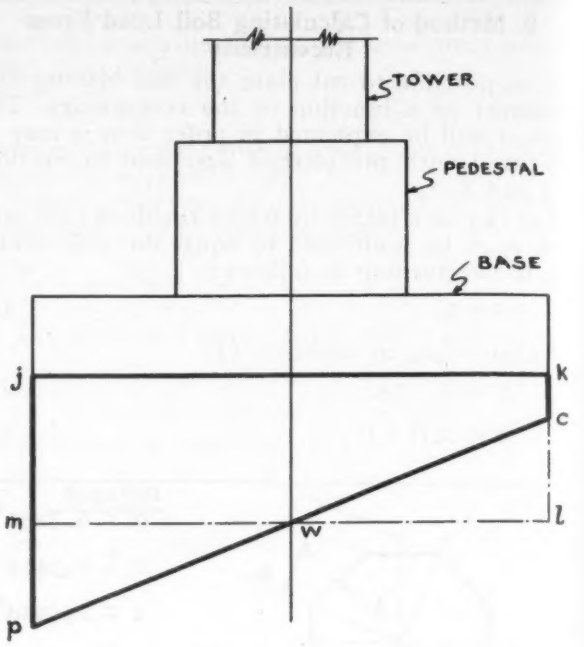

FIGURE 3a

example No. 1 will be calculated (as example No. 3) on the basis of eccentricity. From previous calculations, it was found that:

$M_f = 200{,}000$ foot pounds
$W = 174{,}200$ pounds

Therefore by equation (65)

$$e = \frac{200{,}000}{174{,}200} = 1.15$$

The maximum soil loading due to the dead load (S_1) was found to be 1155 pounds per square foot, and (d_b) is equal to 13.5 feet.

Substituting in equation (73)

$$S = 1155\left(1 + \frac{8.15 \times 1.15}{13.5}\right)$$

$S = 1155 \times 1.693 = 1955$ pounds per square foot.

This checks the value of 1958 pounds per square foot calculated (by slide rule) in Section 7, thus indicating that either method yields the same result.

10. Soil Loading at Any Point

Having calculated the eccentricity, it is a simple matter to determine the unit stress on the soil at any point whose distance from the centroidal axis is (c′).

The unit stress on the soil, from equation (1), is as follows:

$$S = S_1 + S_2 \qquad (1)$$

Since the value of (S_2) for points to the right of the axis is negative, the value of (S) will be:

$$S = S_1 - S_2 \text{ (see equation 1-a)} \qquad (1\text{-b})$$

Equations (1) and (1-b) can be combined as follows:

$$S = S_1 \pm S_2 \qquad (1\text{-c})$$

From equation (2)

$$S_1 = \frac{W}{a} \qquad (2)$$

The value of (S_2) can be written:

$$S_2 = \frac{Wec'}{ar^2} \text{ (see equations 14 and 17)} \qquad (23)$$

Therefore,

$$S = \frac{W}{a} \pm \frac{Wec'}{ar^2}$$

Simplifying:

$$S = \frac{W}{a}\left(1 \pm \frac{ec'}{r^2}\right) \qquad (24)$$

This value of (S) is the total unit stress at any point whose distance (in feet) from the centroidal axis is (c′).

It is important to note that equations (1-a), (14) and (17) referred to above were used to determine the stability and the eccentricity under the poorest condition, which obviously occurs when the dead load is at its minimum. Equation (24) can be used to determine the stress under any dead load, therefore, equation (24) may be based on either (W) or (W_t) depending on the dead load for which the stress is to be determined. It is obvious for this purpose that the same value of the dead load should be used in the calculation of the eccentricity (e), by means of equation (12).

11. Stresses in Tower Shell

The steel shell is required to withstand the stresses resulting from, (a) the internal pressure; (b) the dead load; (c) the overturning moment due to the wind pressure. This discussion will be confined to the stress resulting from the wind pressure.

It may be assumed, in determining the stress due to the wind pressure, that the tower is a vertical beam, and that the wind produces a bending moment. The ordinary formulas for determin-

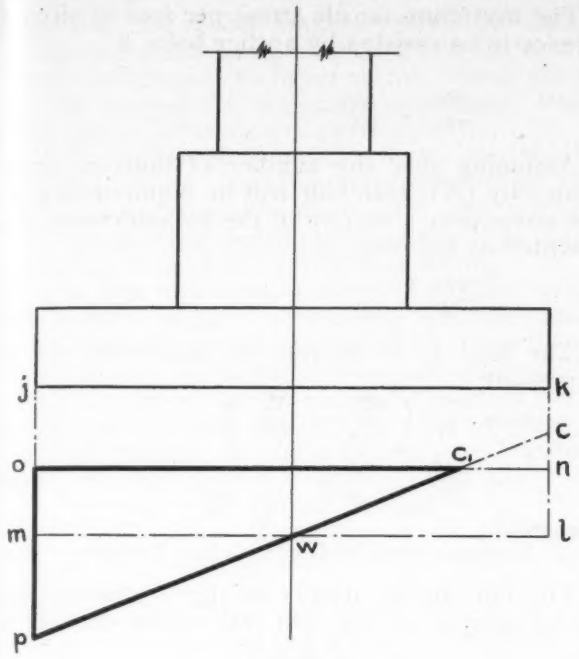

FIGURE 3b

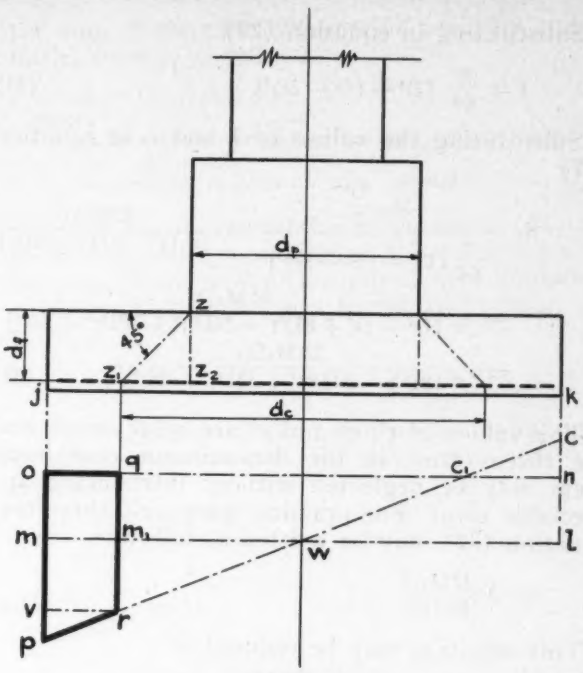

FIGURE 3c

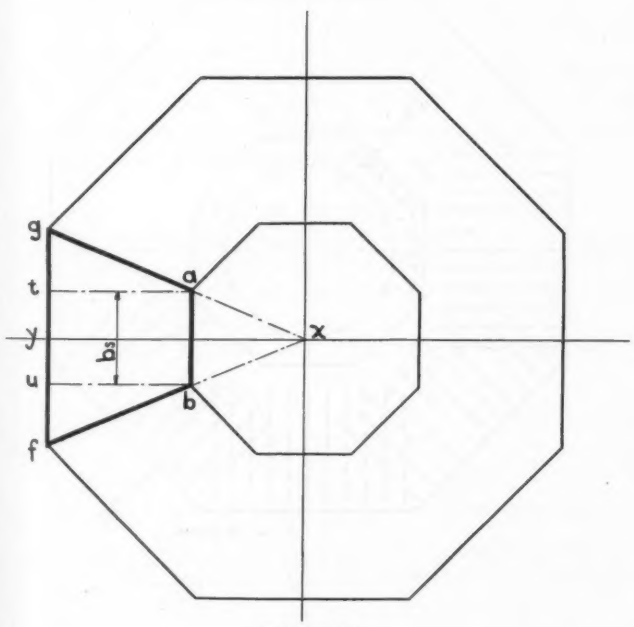

FIGURE 3d

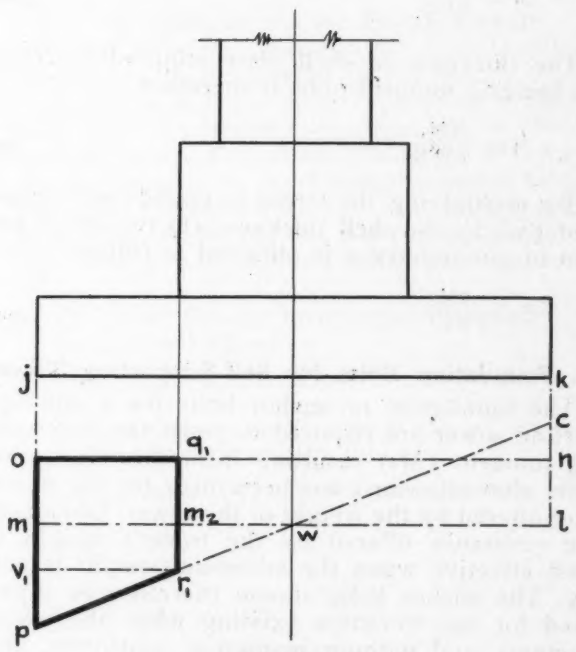

FIGURE 3e

ing bending moment and stress may therefore be applied, as follows:

$$M_t = P_w \left(\frac{H}{2}\right) \quad (26)$$

where

M_t = bending moment about base of tower (foot pounds).

also

$$S_t = \frac{M_t c}{I} \quad (27)$$

where

S_t = unit stress in tower shell due to bending moment (M_t). (lbs./sq. ft.)

Note: The unit stress in the tower shell (S_t) is calculated in pounds per square foot in order to be consistent with the other calculations which are in foot-pound unts. Steel stresses, however, are ordinarily given in pounds per square inch. In order to convert the stress from (pounds/sq. ft.) as calculated, to (pounds/sq. in.) it is necessary to divide (S_t) by 144.

The shell is a hollow cylinder, in which case:

$$c = \frac{D}{2} \quad (28)$$

and

$$I = \frac{\pi}{64} (D^4 - D_1^4) \quad (29)$$

where

D = outside diameter of tower (feet)

D_1 = inside diameter of tower (feet)

when

t = thickness of shell (feet)

and

$$D - D_1 = 2t \quad (30)$$

$$D_1 = D - 2t \quad (31)$$

Substituting in equation (29)

$$I = \frac{\pi}{64}\left[D^4 - (D-2t)^4\right] \tag{31}$$

Substituting the values of I and c in equation (27)

$$S_t = \frac{M_t \frac{D}{2}}{\frac{\pi}{64}\left[D^4 - (D-2t)^4\right]} = \frac{32M_tD}{\pi\left[D^4 - (D-2t)^4\right]}$$

$$= \frac{32\,M_tD}{\pi\left[D^4 - D^4 + 8D^3t - 24D^2t^2 + 32Dt^3 - 16t^4\right]}$$

$$= \frac{32\,M_tD}{\pi\left[8D^3t - 24D^2t^2 + 32Dt^3 - 16t^4\right]} \tag{32}$$

The values of t^2, t^3 and t^4 are quite small and the three terms in the denominator containing them may be neglected without introducing appreciable error. For practical purposes, therefore, equation (32) may be written as follows:

$$S_t = \frac{32M_tD}{8\pi D^3t} \tag{32-a}$$

This equation may be reduced to:

$$S_t = \frac{4M_t}{\pi D^2t} \tag{32-b}$$

The thickness of shell plate required to resist the bending moment only, is therefore

$$t = \frac{4M_t}{\pi D^2S_t} \tag{33}$$

By multiplying the stress in pounds per square foot (S_t) by the shell thickness (t) the stress per foot of circumference is obtained as follows:

$$tS_t = \frac{4M_t}{\pi D^2} \tag{34}$$

12. Foundation Bolts for Self-Supporting Tower

The foundation or anchor bolts for a self-supporting tower are required to resist the overturning moment (M_t) resulting from the wind pressure, after allowance has been made for the resistance offered by the weight of the tower. Obviously the resistance offered by the tower's weight is least effective when the minimum weight is acting. The anchor bolts should therefore be calculated for the condition existing when the tower is empty and without insulation, platforms, etc. This weight will be designated by (W_s).

It was shown that the maximum stress per foot of circumference due to the wind moment can be calculated by equation (34). That equation gives the stress at the circumference of the shell, however, at the present moment it is desired to determine the bolt stress making it necessary to substitute (D_b) in place of (D). The stress per foot of bolt circle circumference can then be written:

$$\frac{4M_t}{\pi D_b^2} \tag{35}$$

where
D_b = diameter of bolt circle (feet).

The compressive stress per foot of circumference due to the weight of the tower is

$$\frac{W_s}{\pi D_b} \tag{36}$$

The maximum tensile stress per foot of circumference to be resisted by anchor bolts is

$$\frac{4M_t}{\pi D_b^2} - \frac{W_s}{\pi D_b} \tag{37}$$

Assuming that the number of bolts is represented by (N), each bolt will be required to carry the stress over a portion of the circumference represented as follows:

$$\frac{\pi D_b}{N} \tag{38}$$

The load to be carried by each bolt can be expressed

$$S_b = \frac{\pi D_b}{N}\left(\frac{4M_t}{\pi D_b^2} - \frac{W_s}{\pi D_b}\right)$$

$$= \frac{4M_t}{ND_b} - \frac{W_s}{N} \tag{39}$$

where
S_b = maximum load on each bolt (pounds).

The nut should always be tight, placing some initial tension on the bolt. Of course due allow-

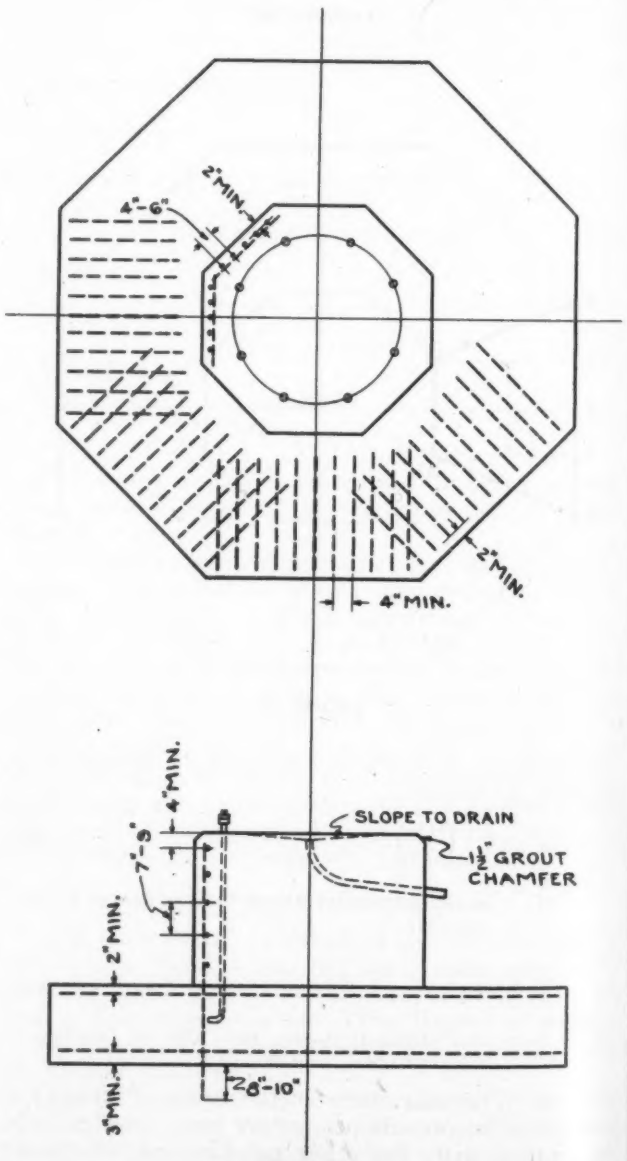

FIGURE 4

ance for the initial tension should be made in determining the size of the bolt, and the strength of the bolt should be based on the area at the root of the thread. An additional allowance, usually ⅛", should be made for corrosion.

The number of foundation bolts should never be less than 8, and should preferably be 12 or more, as the larger the number of bolts, the better the stresses are distributed, and the less danger resulting from a loose nut on one bolt.

The bolt should be embedded in the concrete foundation in such a manner that the holding power of the concrete will be at least equal to the full strength of the bolt. It is common practice to use a washer at the lower end, or to bend the end of the bolt to form an "L" for the purpose of anchoring the bolt in the concrete (see Figure 7).

13. Guyed Towers

In cases where the tower is very high, it is sometimes found desirable to maintain stability by means of guy wires rather than a large foundation. Although it is not uncommon to find two or even three sets of guy wires on one stack, towers seldom have more than one set, and even these cases are rare. This discussion, therefore, will be confined to towers with one set of guy wires.

Four guy wires are usually used for each set, although in some instances three, and in others as many as six have been used. They are attached to a rigid collar which is located at a point approximately 2/3 (sometimes ¾) of the tower height above the foundation.

14. Pull on Guy Wires

The maximum pull on the guy wire occurs when the wind blows along that wire, and each wire must be designed to take care of the entire wind reaction at the collar.

The pull on the guy wire can be expressed as follows:

$$R_g = \frac{R_c}{\text{Sin}\theta} \tag{40}$$

or

$$R_g = R_c \csc \theta \tag{41}$$

where

R_g = pull on guy wire due to wind pressure (pounds)
R_c = horizontal wind reaction at collar (pounds)
θ = angle that the guy makes with the vertical (degrees)

The value of the angle θ will usually lie between 30 and 75 degrees.

The vertical component of the pull on the guy wire can be expressed in any of the following ways:

$$R_g \times \cos\theta \tag{42}$$

$$\frac{R_c \times \cos\theta}{\text{Sin}\,\theta} \tag{43}$$

$$R_c \times \cot\theta \tag{44}$$

It is important to note, however, that there is always some initial tension on the guys which must be considered. This initial tension may be assumed to be 5000 lbs./sq. in., which amounts to 1000 lbs. for ½" wires and 250 lbs. for ¼" wires. The weight of the wires may be neglected, when using these figures.

The actual vertical component will be a function of the total pull on the guy wire, which is the sum of the pull due to wind pressure and the initial tension as follows:

$$R_v = (R_g + R_t)\cos\theta \tag{45}$$

where

R_v = vertical component of pull on guy wire (pounds)
R_t = initial tension on wire (pounds).

The value of the reaction at the collar (R_c) may be determined by calculating the moments about the base of the tower (the top of the foundation).

The wind moment was found by equation (26) to be

$$P_w\left(\frac{H}{2}\right)$$

The resisting moment arm at the collar is h_1, therefore the reaction (R_c) may be calculated as follows:

$$R_c = \frac{P_w\left(\frac{H}{2}\right)}{h_1} \tag{47}$$

or

$$R_c = \frac{P_w H}{2h_1} \tag{48}$$

where

h_1 = height from top of foundation to collar (feet).

15. Foundations for Guyed Towers

It was shown by equation (1) that the total soil loading, to be considered in the design of tower foundations, is the sum of (S_1) which is the dead load, and (S_2) which is the load due to the overturning, or wind moment. In the case of the guyed towers, there is no overturning moment, however, the wind pressure does have an important effect on the foundation, as the soil is required to resist the vertical component of the pull on the guy wires.

For guyed towers, therefore, equation (1) must be revised as follows:

$$S = S_1 + S_g \tag{49}$$

where

S_g = unit soil loading due to the pull on the guy wire. (pounds/sq. ft.)

The value of (S_g) can be determined as follows:

$$S_g = \frac{R_v}{a} \tag{50}$$

From equation (2)

$$S_1 = \frac{W}{a} \tag{2}$$

Substituting in equation (49)

$$S = \frac{W + R_v}{a} \tag{51}$$

16. Foundation Bolts for Guyed Towers

The foundation bolts for guyed towers are required to resist the shearing action of the wind pressure at the base of the tower. It is obvious that ample allowance should be made in the size of the bolts to provide for the initial tension due to tightening the nuts, and also for corrosion.

The shear at the base of the tower, which must be resisted by the bolts, is equal to the horizontal reaction to the wind pressure at that point. This is equal to the difference between the total wind-

pressure and the reaction at the collar and can be expressed as follows:

$$R_b = P_w - R_c \quad (52)$$

where

R_b = horizontal wind reaction, or shear, at the base of the tower. (pounds)

17. Stress in Shell of Guyed Tower

The wind pressure acting on a guyed tower produces a negative bending moment at the collar,

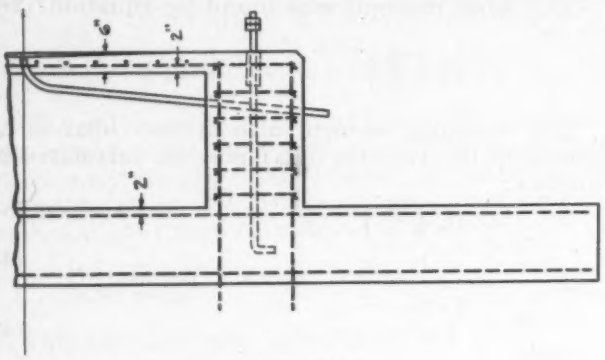

FIGURE 5

and a positive bending moment between the base and the collar. The maximum values of these two moments can be calculated as follows:

$$M_c = -\frac{P_w}{2H}(H - h_1) \quad (53)$$

$$M_p = P_w H\left(1 - \frac{H}{2h_1}\right) \quad (54)$$

where

M_c = negative bending moment at collar. (foot pounds)

M_p = maximum positive bending moment between collar and base. (foot pounds).

Having determined the bending moments, the stress in a given shell, or the shell thickness required to resist the bending moment may be calculated by substituting the value of (M_c) or (M_p) in place of (M_t) in equations (32-b) and (33).

18. Piling

In cases where the safe soil loading is very low, it is sometimes found difficult to design an ordinary foundation which will not overload the soil. In such cases it is desirable to support the load on piles rather than on the soil.

Wooden piles are ordinarily used, and they vary greatly in length, depending on the nature of the soil. The diameter at the lower end is about 6″; and the diameter at the top is about 10″ for piles not over 25 feet in length, and 12″ for longer piles.

Wooden piles generally depend on the frictional resistance of the ground for their load carrying capacity, as they have comparatively little strength as columns. The safe load which a pile will support varies greatly in different localities. Building laws sometimes govern the pile loading, and in such cases, the load is usualy about 20 tons per pile, although occasionally 25 tons is permissible.

When conditions are not definitely known, however, the only safe procedure is to drive a few piles for test purposes. The common method of calculating the safe load is by means of what is known as the "Engineering News Formula," which has been widely published. There are really two formulas; one for piles driven with a drop hammer, and another for piles driven with a steam hammer, as follows:

For drop hammer

$$P = \frac{2W_h f}{p_h + 1.0} \quad (55)$$

For steam hammer

$$P = \frac{2W_h f}{p_h + 0.1} \quad (56)$$

where

P = safe load which each pile will support. (pounds)

W_h = weight of hammer. (pounds)

f = height of hammer fall. (feet)

p_h = penetration or sinking under the last blow, on sound wood. (inches)

Care should be exercised in driving piles, to assure that they are deep enough to develop their full strength, but they should not be driven too much, as this practice results in splitting or breaking, and greatly reduces the load carrying capacity.

Although piles have been driven with a center to center spacing as small as 2′ 6″, it is strongly recommended that this distance be not less than 3′ 0″. Closer spacing disturbs the ground sufficiently to greatly reduce or destroy the frictional resistance.

The top of the piles should always be cut off below the water level, otherwise they will decay rapidly.

The reinforced concrete cap is constructed on top of the piles in such a manner that the piles extend about 6″ into the concrete (see Figure 6).

19. Stresses in Foundation

After having selected a foundation of such size and shape as to fulfill the requirements of the problem from the standpoint of stability and soil loading, it becomes necessary to calculate the stresses in the foundation itself, to see that they do not exceed the allowable limits.

The first step in this procedure is to determine

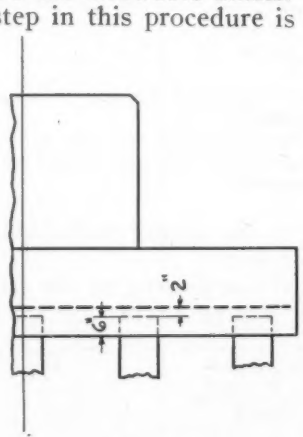

FIGURE 6

the loading, which consists primarily of the upward reaction of the soil. Figure 3 represents the plan view of a typical (octagonal) foundation, and Figure 3a shows the loading diagram. In this diagram the dead load (S_1) is represented by the rectangle (jklm). The wind load (S_2), which is positive on one side of the centerline, is indicated by the triangle (mpw). On the opposite side of

the centerline the wind load is negative, thereby counteracting a portion of the dead load (wlc). The actual soil loading will therefore be represented by the area (jkcp). However, the weight of the base, and of the earth fill above the base (area jkno Figure 3b) do not exert any upward force on the foundation, and may therefore be deducted from the total load, for the present purpose. The *effective* upward reaction will then be the area ($oc_1 p$) in Figure 3b.

19a. Diagonal Tension

The vertical shear, resulting from the upward reaction of the soil, produces diagonal tension stresses in the foundation. The critical section lies at a distance from the face of the pedestal equal to the effective depth of the base, as indicated by point (Z_1) in Figure 3c. In other words, the foundation tends to break along line (ZZ_1). The vertical shear to be resisted is equal to the net soil pressure on the part of the foundation outside the critical section.

For design purposes, therefore, the load will be the area (oqrp), (Figure 3c) applied over the area (a_1 b_1 fg), (Figure 3). Because of the irregular shape of the load diagram, its magnitude can be more conveniently calculated by breaking it up into its component parts, the total load (V_s) being the sum of the individual loads, as follows:

Shape of part	Outline in plan (Fig. 3)	Outline in elevation (Fig. 3c)
Rectangular Prism	a_2 b_1 u_1 t_1	oqrv
Wedge	a_1 t_1 g	oqrv
Wedge	b_1 fu_1	oqrv
Wedge	a_1 b_1 u_1 t_1	rvp
Pyramid	a_1 t_1 g	rvp
Pyramid	b_1 fu_1	rvp

The unit stress (diagonal tension) resulting from this vertical shear load can be determined as follows:

$$f_d = \frac{V_s}{b' j d_f} \qquad (80)$$

where

f_d = unit stress in concrete (in diagonal tension) due to vertical shear load. (pounds/sq. in.)
V_s = vertical shear load, outside the critical section (see Figures 3 and 3c). (pounds)
b' = width of critical section which serves to resist diagonal tension stresses (line a_1 b_1 Figure 3). (inches)
j = ratio of lever arm of resisting couple to depth (d_f) (see Table 2).
d_f = effective depth of base measured from top of base to centerline of reinforcing steel. (inches)

Example No. 4. Check diagonal tension stresses in the foundation considered in example No. 1:

Figure unit soil loading due to weight of base and earth (see Section 7):

Concrete base	63,000 lbs.	
Earth fill	32,700 lbs.	
Total	95,700 lbs.	
Unit soil loading	$= \frac{95{,}700 \text{ lbs.}}{151 \text{ sq. ft.}} =$	633 lbs./sq. ft.

Total unit dead load (S_1) (jm, figure 3c)	=	1,155 lbs./sq. ft.
Unit dead load due to weight of base and earth fill (jo)	=	633
Net soil load (om)	=	522 lbs./sq. ft.
Maximum unit wind load (S_s), (mp)	=	803
Maximum effective unit shear load (op)		1,325 lbs./sq. ft.

Line $(mw) = \frac{162}{2} = 81''$

$d_p = 72''$. $d_f = 21''$. $d_b = 162''$
$d_c = 72 + 21 + 21 = 114''$
Line $(gf) = 67.1''$ (see Table 1).
Line $(m_1 w) = \frac{114}{2} = 57''$.
Line $(a_1 b_1) = \frac{67.1 \times 57}{81} = 47.2'' = (b')$.
Line $(gt_1) = \frac{67.1 - 47.2}{2} = 9.95''$
Line $(a_1 t_1) = \frac{162 - 114}{2} = 24''$

Factor $j = .87$ (see Table 2).
Load $(m_1 r) = \frac{803 \times 57}{81} = 565$ lbs./sq. ft.
Load $(qr) = 565 + 522 = 1{,}087$ lbs./sq. ft.

Calculate shear load (V_s)

$47.2'' \times 24'' \times \frac{1{,}087 \text{ lbs./sq. ft.}}{144 \text{ sq. in.}}$	= 8,550 lbs.
$9.95'' \times 24'' \times \frac{1{,}087}{144}$	= 1,805
$47.2 \times 24 \times \frac{238}{2 \times 144}$	= 935
$\frac{9.95 \times 238 \times 24 \times 2}{3 \times 144}$	= 263
Total (V_s)	= 11,558 lbs.

Calculate unit stress in concrete (equation 80)

$$f_d = \frac{11{,}558}{47.2 \times .87 \times 21} = 13.4 \text{ lbs./sq. in.}$$

This stress is satisfactory, as 40 lbs./sq. in. would be allowed (see Table 2).

19b. Depth of Slab Required for Punching Shear

The thickness of the foundation slab (bottom course) must also be sufficient to withstand the tendency to shear along line (Z-Z_2), (Figure 3c) at the edge of the pedestal. This shearing load may be determined as follows:

$$S_3 = S_4 + S_5 \qquad (81)$$

The stresses in this case are not distributed over the foundation area, but are concentrated at the edge of the pedestal.

Then

S_3 = total maximum unit shearing load. (lbs. per lineal foot of pedestal perimeter).
S_4 = unit shearing load due to dead load. (lbs. per lineal foot of pedestal perimeter).
S_5 = maximum unit shearing load due to overturning moment. (lbs. per lineal foot of pedestal perimeter).

The value of (S_4) can be determined by adding the weight supported by the pedestal to the weight of the pedestal itself, subtracting the load-carrying value of the soil directly under the pedestal, and dividing the difference by the perimeter of the pedestal base as follows:

$$S_4 = \frac{W_s + W_s + W_p - (a_p S_{s11})}{L_p} \qquad (82)$$

where

W_p = weight of foundation pedestal (top course). (pounds)
a_p = plan area of foundation pedestal. (sq. ft.)
S_{s11} = maximum allowable unit soil loading. (pounds/sq. ft.)
L_p = perimeter of foundation pedestal. (feet)

Obviously, if the value of (a_p S_{s11}) is equal to

or greater than $(W_s + W_a + W_p)$, the value of (S_4) becomes zero, and (S_3) will then be equal to (S_5).

The value of (S_5) can be determined in a manner somewhat similar to that proposed in Section 12. In that section the overturning load was calculated as a function of the periphery of the foundation bolt circle, by means of equations (27) and (35). The bolt circle was assumed to be a hollow cylinder, the wall thickness being infinitely small, as compared with the diameter.

In the determination of the shear at the edge of the foundation pedestal, a similar procedure may be followed, substituting (M_f) in place of (M_t), and appropriate values of (I) and (c) in equation (27), depending on the shape of the pedestal.

Reduced to their simplest forms, the equations for the ordinary foundation shapes are as follows:

Octagon

$$S_s = \frac{M_f}{.814 d_p^3} \qquad (83)$$

Hexagon

$$S_s = \frac{M_f}{.832 d_p^3} \qquad (83a)$$

Square

$$S_s = \frac{M_f}{.943 d_p^3} \qquad (83b)$$

Circle

$$S_s = \frac{M_f}{.785 d_p^3} \qquad (83c)$$

In these equations (d_p) is the short diameter of the pedestal (feet).

Once the shearing load (S_3) per foot of pedestal perimeter is known, it is a simple matter to calculate the unit stress in the concrete, by dividing (S_3) by the effective depth of the base, as follows:

$$f_p = \frac{S_3}{12 d_f} \qquad (84)$$

where

f_p = unit stress in concrete base due to punching shear. (pounds/sq. in.)

Note: The factor 12 is introduced for the purpose of converting (S_3) from (pounds/lin. foot) to (pounds/lin. inch) as unit stress (f_p) is in terms of (pounds/sq. in.).

Example No. 5. To illustrate the procedure, the punching shear will be calculated for the foundation considered in example No. 1.

Calculate dead load shear (S_4) by equation (82)

$W_s = 30{,}000$ lbs. $\qquad W_a = 48{,}500$ lbs.
$W_p = 119.2$ cu. ft. $\times$ 150 lbs. $= 17{,}850$ lbs.
$a_p = 29.8$ sq. ft. $\qquad S_{all} = 2{,}000$ lbs./sq. ft.
$L_p = 2.484 \times 8 = 19.87$ ft.

$$S_4 = \frac{30{,}000 + 48{,}500 + 17{,}850 - (29.8 \times 2{,}000)}{19.87}$$

$= 1{,}850$ lbs./lin. foot.

Calculate shearing stress due to overturning moment (S_5) by equation (83)

$M_f = 200{,}000$ foot pounds (see section 7).
$d_p^3 = 6^2 = 36$.

$$S_5 = \frac{200{,}000}{.814 \times 36} = 6{,}820 \text{ pounds/lin. foot}$$

$S_3 = 1{,}850 + 6{,}820 = 8{,}670$ pounds/lin. foot. (81)
$d_f = 21''$.

$$f_p = \frac{8{,}670}{12 \times 21} = 34.4 \text{ pounds/sq. in.} \qquad (84)$$

This stress is satisfactory, as 120 pounds/sq. in. is permissible. (See Table 2.)

In the case of guyed towers, or stacks, the shear load due to overturning moment (S_5) does not apply, but is replaced by

$$\left(R_g / L_p \right)$$

which is the load due to the pull on the guy wires, as follows:

$$S_{3(guyed)} = S_4 + \frac{R_g}{L_p} \qquad (81a)$$

19c. Reinforcement of Base for Upward Bending Reaction of Soil

In designing the base of the foundation to resist the bending moment due to the upward reaction of the soil, the critical section is located at line (ab), (Figure 3d) along one face of the pedestal (top course). The moments are therefore figured about line (ab), on the basis of the load on the trapezoid (abfg). The load which serves to produce the bending moment in the base is the "unbalanced" upward reaction. Since the weight of the base, and the weight of the earth fill above the base do not contribute to the bending moment, they may be deducted from the total load when calculating the bending moment. The effective loading will therefore be represented by the area (o q_1 r_1 p) Figure 3e.

The load is assumed to be applied at its center of gravity, and the moment figured about line (ab). Due to the irregular shape of the load diagram, it is difficult to locate the center of gravity, and it is therefore more convenient to break it up into its component parts (prisms, wedges, pyramids, etc.), and figure the moment of each part separately. Obviously, the total moment (M_b) will be the sum of the individual moments.

In the case of the rectangular prism, the lever arm used in figuring its moment will be one half of the distance from point (a) to point (t), (Figure 3d). In the case of the wedges and pyramids, the lever arm will be two-thirds of the distance from point (a) to point (t).

The individual components and their respective lever arms are as follows:

	Outline in plan, Fig. 3d	Outline in elevation, Fig. 3c	Lever Arm
Rectangular Prism	abut	q_1 r_1 v_1 o	$\frac{\text{Distance (at)}}{2}$
Wedge	atg	q_1 r_1 v_1 o	$\frac{\text{Distance (at)} \times 2}{3}$
Wedge	bfu	q_1 r_1 v_1 o	$\frac{\text{Distance (at)} \times 2}{3}$
Wedge	abut	r_1 v_1 p	$\frac{\text{Distance (at)} \times 2}{3}$
Pyramid	atg	r_1 v_1 p	$\frac{\text{Distance (at)} \times 2}{3}$
Pyramid	bfu	r_1 v_1 p	$\frac{\text{Distance (at)} \times 2}{3}$

In calculating the amount of reinforcement required, it is assumed that the portion of the base designated (abut), (Figure 3d) acts as a cantilever beam (of rectangular cross-section) having a width equal to one face of the pedestal (ab), a depth equal to the effective depth of the base (d_f) and a length equal to (at).

Having calculated the bending moment as proposed above, the next step is to check the depth

of the base, and determine the amount of reinforcing steel required. These calculations are based on the commonly accepted formulas for reinforced concrete. (It should be noted that for this purpose it is more convenient to figure the moments in terms of inch-pounds, as the stresses in concrete and steel are usually given as pounds per square inch, whereas in figuring soil loading foot-pound units are used, as soil loading is usually stated as pounds per square foot.)

For *balanced design,* that is, conditions in which both concrete and steel are stressed to their full allowable capacity, the required depth (d_f) of the base may be determined as follows:

$$d_f = \sqrt{\frac{M_b}{f_s\, p_r\, j b_s}} \qquad (85)$$

where

d_f = depth of base, measured from top of concrete to centerline of reinforcing steel. (inches)
M_b = bending moment in base. (inch-pounds)
f_s = safe working stress, reinforcing steel in tension. (pounds per sq. in.)
$p_r = \left(A_s \diagup b_s\, d_f \right)$ = ratio of effective area of reinforcing steel to effective area of concrete.
j = ratio of lever arm of resisting couple to depth (d_f).
b_s = width of beam (line ab, Figure 3d). (inches)
A_s = effective cross sectional area of steel reinforcement in tension. (square inches)

If the design is balanced, that is, the actual depth of the base (d_f) is that calculated by equation (85), the value of (A_s) may be determined as follows:

$$A_s = b_s\, d_f\, p_r \qquad (86)$$

If the depth (d_f) is greater than required by equation (85), in which case the steel is stressed to its full capacity but the concrete is understressed, the value of (A_s) becomes:

$$A_s = \frac{M_b}{f_s\, j d_f} \qquad (87)$$

If the depth (d_f) is less than required by equation (85), it is recommended that the dimensions of the base be changed to give the required depth. In case circumstances make it impossible to increase (d_f) to the required dimension, it will be necessary to increase the amount of reinforcement used. The determination of the amount of reinforcement required for such special cases is beyond the scope of this article, and reference is made to the various publications dealing specifically with concrete design for further details.

Having calculated the cross sectional area of steel required, a selection is made as to the diameter, shape, number and spacing of bars which will give the required area. It is recommended that the center-to-center distance be about 4 inches if possible, but not less than 2½ times the bar diameter for round bars, or 3 times the side dimension for square bars. Generally speaking, a large number of small bars (½, ⅝, or ¾ inch) are preferable to a smaller number of larger bars.

It should be borne in mind that the area of reinforcement determined above is the amount required for that portion of the foundation having a width equal to (ab), Figure 3d, which was assumed to be the cantilever beam carrying the entire bending load. This amount of reinforcement should therefore be placed within the limits of the beam width (ab). However, additional reinforcement should be installed to reinforce the base between the points (gt), and also at (uf), using the same type and spacing of bars as determined for the beam section (ab). This additional reinforcement insures that the entire area of the base is reinforced and weak spots eliminated.

Obviously, the reinforcing bars should extend entirely across the base. Also, there should be a set of reinforcing bars parallel to each of the axes, i.e., four sets of bars for an octagonal base, three sets for a hexagon, etc., thus providing strength in all directions.

There should be at least 3 inches of concrete below the reinforcing bars at the bottom of the base. Reinforcement in other parts of the foundation should be covered with not less than 2 inches of concrete.

Example No. 6. Determine bottom reinforcement for the foundation referred to in example No. 1.

Figure bending loads

$$\text{Line } (m_2\, w) = \frac{72''}{2} = 36''$$

$$\text{Load } (m_2\, r_1) = \frac{803 \times 36}{81} = 357 \text{ pounds/sq. ft.}$$

$$\text{Load } (q_1\, r_1) = 357 + 522 = 879 \text{ pounds/sq. ft.}$$

$$\text{Load } (v_1\, p) = 803 - 357 = 446 \text{ pounds/sq. ft.}$$

Figure moment (M_b)

Line (ab) = 29.8″
Line (ta) = 45″
Line (gt) = 18.65″

$$\frac{29.8'' \times 45''}{144 \text{ sq. in.}} \times 879 \text{ pounds/sq. ft.} \times \frac{45''}{2} = 184{,}000 \text{ in.-lbs}$$

$$\frac{18.65 \times 45}{144} \times 879 \times \frac{45 \times 2}{3} = 153{,}000$$

$$\frac{29.8 \times 45}{144} \times \frac{446}{2} \times \frac{45 \times 2}{3} = 62{,}300$$

$$\frac{18.65 \times 446 \times 45}{144 \times 3} \times 2 \times \frac{45 \times 2}{3} = 51{,}900$$

Total (M_b) = 451,200 in.-lbs.

Check depth of base for balanced design (equation (85)

$f_s = 18{,}000$
$p_r = .0089$
$j = .87$
$b_s = 29.8''$
$f_s\, p_r\, j = 138.7$

$$d_{f\,(\text{balanced})} = \sqrt{\frac{451{,}200}{138.7 \times 29.8}} = 10.5''$$

Since the actual depth is 21 inches, whereas only 10.5 inches would be required, the concrete will be understressed, and the area of reinforcing steel should be calculated by equation (87).

$$A_s = \frac{451{,}200}{18{,}000 \times .87 \times 21} = 1.37 \text{ sq. in.}$$

Use ½ inch deformed square bars (.25 sq. in. area).

Number required $\frac{1.37}{.25} = 5.5$. Use 6 bars within the width of beam (ab).

Spacing $\frac{29.8''}{6} = 4.96''$. Use 5-inch spacing entirely across side (gf), which will require $\frac{67.1''}{5}$ = 13 bars per set. Four sets of bottom reinforcing bars will be required for the octagonal foundation.

19d. Reinforcement to Resist Stresses Due to Uplift

As explained previously, the wind moment creates a positive soil load on one side of the centerline, and a negative load on the opposite side. In other words, the action of the wind tends to lift the foundation on the negative side. This upward force, or "uplift" effect, is resisted by the weight of the concrete base itself, and by the weight of the earth fill on top of the base. It therefore becomes necessary to reinforce the top of the base, to resist the resulting negative bending moment.

The procedure is quite similar to that described for the upward soil reaction (Section 19c). The load acts on the area (abfg), and the outline of the theoretical beam carrying the load is (abut) as in Section 19c. However, in this case the load is the weight per square foot of concrete base, plus the weight per square foot of the earth fill, and is uniformly distributed, thus simplifying the calculations. After figuring the moments, the reinforcement is determined in exactly the same manner as explained in Section 19c, using the equation

$$A_s = \frac{M_u}{f_s\, jd_f} \qquad (87a)$$

In this case, (d_f) is the depth of the base from the centerline of the upper layer of reinforcement to the bottom of the base, and (M_u) is the bending moment due to the uplift forces (inch-pounds).

Example No. 7. Determine top reinforcement to resist uplift in the foundation referred to in example No. 1.

Weight of concrete 150 lbs./cu. ft. × 2 ft.	= 300 lbs./sq. ft.
Weight of earth 90 lbs./cu. ft. × 3 ft.	= 270 lbs./sq. ft.
Total	= 570 lbs./sq. ft.

TABLE 2

Constants Applying to Foundation Design

Mixture: Cement / Sand / Coarse Aggregate		1 / 2 / 4	1 / 2 / 5
f_b	Safe bearing load on concrete (lbs./sq. in.)	500	375
f'_c	Ultimate compressive strength (lbs./sq. in.)	2,000	1,500
f_c	Safe unit stress in extreme fiber of concrete (in compression)—(lbs./sq. in.)	800	600
f_d	Safe unit stress in concrete due to vertical shear (diagonal tension) (lbs./sq. in.)	40	30
f_p	Safe unit stress in concrete base due to punching shear. (lbs./sq. in.)	120	90
f_s	Safe working stress, steel reinforcement in tension. (lbs./sq. in.)	18,000	18,000
(f_s j)	(inch-pounds)	15,600	16,000
(f_s jp_f)	(inch-pounds)	138.7	88.9
j	Ratio, lever arm of resisting couple to depth (d_f)	.87	.89
$\left[n = E_c/E_s\right]$	Ratio, modulus of elasticity of steel to that of concrete	15	15
$\left[p_f = A_s/b_s d_f\right]$	Ratio, effective area of tension reinforcement to effective area of concrete	.0089	.0056
*u	Safe bond stress (concrete to steel reinforcement) per unit of area of surface of bar. (pounds)		
	Plain bars	60	45
	Deformed bars	75	56

* These figures may be slightly increased by making "U"—bends on the ends of the reinforcing bars.

Note:—The 1:2:4 mixture is recommended as most satisfactory for foundations of the type. The constants for the 1:2:5 mixture are presented as a matter of interest.

Moment

$$\frac{29.8 \times 45}{144} \times 570 \times \frac{45}{2} = 119{,}000 \text{ in.-lbs.}$$

$$\frac{18.65 \times 45}{144} \times 570 \times \frac{45 \times 2}{3} = 99{,}500$$

Total (M_u) = 218,500 in.-lbs.

From equation (87a)

$$A_s = \frac{218{,}500 \text{ inch lbs.}}{18{,}000 \times .87 \times 22} = .636 \text{ sq. in. within beam width (29.8")}$$

Use ½-inch deformed square bars, at 10-inch centers.

19e. Bond

In order for the reinforcement to be effective, the strength of the bond between concrete and steel must be sufficient to permit the reinforcement to develop its full strength. The bond stress may be calculated by means of the following formula:

$$u = \frac{V_s}{\Sigma_o\, jd_f} \qquad (88)$$

where

u = bond stress per unit of area of surface of bar. (pounds)

Σ_o = sum of perimeters of bars within the limits of the beam width (ab). (inches)

Example No. 8. Check bond stresses in example No. 1.

Bottom reinforcement

V_s = 11,578 lbs. (See example No. 4)

$\Sigma_o = 6 \times .5 \times 4 = 12"$

By equation (88)

$$u = \frac{11{,}578}{12 \times .87 \times 21} = 53 \text{ lbs.}$$

Bond stress for bottom reinforcement is satisfactory, as 75 pounds is permissible (see Table 2).

Top reinforcement

Figure shear

$$\frac{47.2" \times 24"}{144} \times 570 \text{ lbs.} = 4{,}480 \text{ lbs.}$$

$$\frac{9.95 \times 24}{144} \times 570 = 947$$

Total (V_s) = 5,427 lbs.

$\Sigma_o = 3 \times .5 \times 4 = 6$

$$u = \frac{5427}{6 \times .87 \times 22} = 48 \text{ lbs.} \qquad (88)$$

The bond stress in top reinforcement is satisfactory, as 75 pounds would be allowed.

19f. Bearing Stresses

The bearing stresses (where the steel tower rests on the concrete pedestal) seldom cause any difficulty, but should be checked as a safety precaution. The bearing stresses consist of the stress due to wind pressure, plus the stress due to the dead load as follows:

$$\text{Bearing stress} = \frac{4M_t}{\pi D_1^2} + \frac{W_s}{\pi D_1} \qquad (37a)$$

(See Sections 11 and 12.)

Equation (37a) gives the bearing stress in pounds per lineal foot of shell circumference. These stresses are spread over the area of the base ring, therfore for practical purposes the unit bearing stress can be determined as follows:

$$f_b = \frac{\frac{4M_t}{\pi D_1^2} + \frac{W_s}{\pi D_1}}{12r_w} \qquad (37b)$$

in which

r_w = width of the tower base ring. (inches)
f_b = unit compression stress on concrete. (pounds/sq. in.)

Equation (37b) may be modified slightly, depending on the exact shape and arrangement of the base ring (or base plate), but in the majority of cases it may be used in the above form with reasonable accuracy.

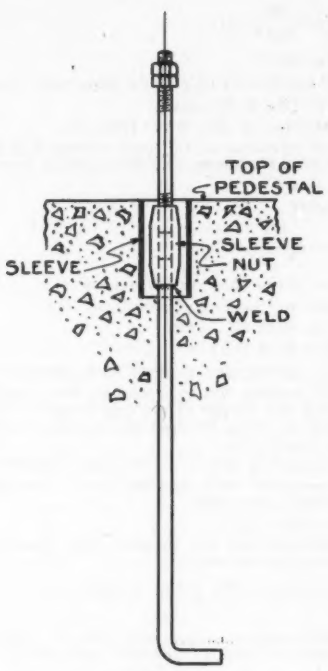

FIGURE 7

For guyed towers, equation (37b) becomes:

$$f_{b\,(guyed)} = \frac{\frac{4M_t}{\pi D_1^2} + \frac{R_v}{\pi D_1}}{12r_w} \qquad (37c)$$

19g. Allowable Stresses in Foundation

It is to be noted that in actual practice the depth of the base in the examples given above could be reduced, if desired. All of the stresses for diagonal tension, punching shear, bending (upward and downward) and bond in the reinforcement are well below the allowable values. As the examples in this case are given for illustration only, the design has not been changed to take maximum advantage of the allowable stresses.

The stresses in foundations of this type should not exceed those commonly accepted as good engineering practice in reinforced-concrete design, for the particular mixture of concrete used. As a matter of convenience Table 2 is presented to show allowable stresses and miscellaneous constants applying to two grades of concrete quite generally used for foundations. It is strongly recommended that the 1:2:4 mixture be used in practice, the figures for the 1:2:5 mixture being shown primarily as a matter of interest.

19h. Suggestions and Recommendations

The calculations explained above provide for reinforcement to resist the stresses due to the various types of loading. It is good practice, however, to install additional steel as a means of tying the foundation together, to form an integral unit. The same size bars are used for this purpose as for the main slab reinforcement, and the designer must use his own judgment as to the number and location of the bars. Figure 4 represents what is considered good practice, and is offered as a guide.

In the case of very large foundations, considerable concrete and weight may be saved by constructing the pedestal with a hollow center, as illustrated in Figure 5. Of course, the inside form is left in place. It should be noted that the base slab extends all the way across, to provide protection and bond for the reinforcing bars.

Foundations supported on piles should be so constructed as to allow the tops of the piles to extend about 6 inches into the base, with the bottom reinforcement about 2 inches above the piles. (See Figure 6.)

Considerable inconvenience is sometimes encountered in setting the tower in place, due to the difficulty of lowering the heavy vessel over the foundation bolts without bending some of them or damaging the threads. Figure 7 illustrates a method of overcoming this difficulty. A sleeve nut is welded to the top of the bolt, and so placed that the top of the nut lies slightly below the surface of the concrete, with a sheet metal sleeve around it. The tower may then be placed in position without interference from the bolts. Stud bolts are next inserted through the lugs on the tower, and screwed into sleeve nuts from the top.

Nomenclature

A_s = effective cross sectional area of steel reinforcement in tension (square inches)

For balanced design

$$A_s = b_s\, d_f\, p_r \qquad (86)$$

If depth (d_f) is greater than required by equation (85)

$$A_s = \frac{M_b}{f_s\, jd_f} \qquad (87)$$

For top reinforcement of slab to resist uplift stresses:

$$A_s = \frac{M_u}{f_s\, jd_f} \qquad (87a)$$

a = area of base of foundation (sq. ft.)
a_p = plan area of foundation pedestal (sq. ft.)
B = barometric pressure (inches H_g)
b_s = width of the critical section (equal to the width of the face of the pedestal) assumed to act as a cantilever beam resisting the bending stresses (line ab, Figure 3d) (inches)
b' = width of critical section which serves to resist the diagonal tension stresses. (line a_1 b_1, Figure 3.) (inches)
c = distance from neutral axis of foundation base to point of maximum stress. (feet)
c' = distance from centroidal axis of foundation base to any point under consideration. (feet)
D = outside diameter of tower. (feet)
D_1 = inside diameter of tower. (feet)
D_o = tower diameter measured over insulation. (feet)
D_b = diameter of foundation bolt circle. (feet)
d_b = short diameter of foundation base. (feet)
d_c = short diameter of critical section for diagonal tension stresses (see Figures 3 and 3c). (inches)
d_f = effective depth of base of foundation, measured from top of base to centerline of reinforcing steel. (inches)

d_p = short diameter of foundation pedestal. (feet)
E_c = modulus of elasticity of concrete.
E_s = modulus of elasticity of reinforcing steel.
e = eccentricity. (feet)
This factor is the distance from the centroidal axis of the foundation to the point at which the resultant of the dead load and the wind load intersects the base of the foundation. The eccentricity can be calculated as follows:

$$e = \frac{M_f}{W_t} \quad (12)$$

Equation (12) gives the eccentricity at the condition of poorest stability, that is, with the minimum dead load. This is the value which ordinarily is used for design purposes, however, it is obvious that the eccentricity for maximum dead load conditions can be calculated by substituting the value of (W) in equation (12) in place of (W_t). The *maximum* value which it is possible for (e) to have and still maintain the stability of the foundation is

$$e_{max} = \frac{r^2}{c}, \text{ or} \quad (19)$$

$$e_{max} = \frac{Z}{a} \quad (19a)$$

Values of (e_{max}) for various foundation shapes are as follows:

Octagon: $e_{max} = 0.122d$ (22)
Hexagon: $e_{max} = 0.121d$ (22a)
Square: $e_{max} = 0.118d$ (22b)
Circle: $e_{max} = \frac{d}{8}$ (22c)

The value of (e) as calculated by equation (12), and based on the minimum dead load (W_t) should *never* exceed the value calculated by equations (19) or (19a).

F = barometric pressure. (inches H_g)
f = height of hammer fall. (feet)
f_b = unit bearing stress on concrete. (pounds/sq. in.). (See equations 37b and 37c)
f_c = safe unit stress in extreme fiber of concrete (in compression). (pounds/sq. in.)
f_c' = ultimate compressive strength of concrete. (pounds/sq. in.)
f_d = unit stress in concrete (in diagonal tension) due to vertical shear load. (pounds/sq. in.)
f_p = unit stress in concrete base due to punching shear. (pounds/sq. in.)

$$f_p = \frac{S_3}{12d_f} \quad (84)$$

f_s = safe working stress, steel reinforcement in tension. (pounds/sq. in.)
H = height of tower. (feet)
h_f = height of foundation. (feet)
h_1 = height of collar (to which the guy wires are attached) above foundation. (feet)
I = moment of inertia of the base of the foundation. (based on dimensions in feet)
j = ratio of lever arm of resisting couple to depth d_f. (See table 2)
k = factor by which the soil loading due to dead load must be multiplied to equal the soil loading due to overturning, as follows:

$$kS_1 = S_2, \text{ also} \quad (57)$$

$$k = \frac{ea}{Z} \quad (68)$$

Values of k for various foundation shapes are as follows:

Octagon: $k = \frac{8.15e}{d}$ (72)
Hexagon: $k = \frac{8.32e}{d}$ (72a)
Square: $k = \frac{8.47e}{d}$ (72b)
Circle: $k = \frac{8.01e}{d}$ (72c)

L = lever arm of wind load (feet) to be calculated as follows:

$$L = h_f + \frac{H}{2} \quad (9)$$

L_p = perimeter of foundation pedestal. (feet)
M_b = bending moment in base. (inch-pounds)
M_c = negative bending moment at collar. (foot-pounds) (see equation 53)
M_f = overturning moment about base of foundation. (foot-pounds)

$$M_f = P_w L \quad (7)$$

M_p = maximum positive bending moment between collar and base. (foot pounds) (see equation 54)
M_t = bending moment about base of tower. (foot-pounds)

$$M_t = P_w \left(\frac{H}{2}\right) \quad (26)$$

M_u = bending moment in base, due to uplift forces. (inch-pounds)
N = number of foundation bolts
n = (E_s/E_c) = ratio, modulus of elasticity of steel to that of concrete.
P = safe load which each pile will support. (pounds)
P_w = total wind load (pounds) to be calculated as follows:

$$P_w = p_e \ D_o \ H \quad (8)$$

p = wind pressure on a flat surface. (pounds per sq. ft.)
p_e = wind pressure on projected area of a cylindrical tower. (pounds per sq. ft.)
p_h = penetration or sinking of pile under the last hammer blow, on sound wood. (inches)
p_r = ratio, effective area of reinforcing steel to effective area of concrete.

$$p_r = \left(A_s / b_s d_f\right)$$

R_b = horizontal wind reaction or shear at base of tower. (pounds)
R_c = horizontal wind reaction at collar. (pounds)
R_g = pull on guy wire due to wind pressure. (pounds)

$$R_g = \frac{R_c}{\sin\theta} \text{ or,} \quad (40)$$

$$R_g = \csc\theta \quad (41)$$

R_v = vertical component of pull on guy wire. (pounds)

$$R_v = (R_g + R_t)\cos\theta \quad (45)$$

R_t = initial tension on guy wire. (pounds)
r = radius of gyration of the base of the foundation (feet). Its relation to the moment of inertia can be expressed as follows:

$$I = ar^2 \quad (17)$$

rearranging:

$$r = \sqrt{\frac{I}{a}} \quad (25)$$

r_w = width of tower base ring. (inches)
S = total unit soil loading. (pounds/sq. ft.)

$$S = S_1 + S_2 \quad \text{also,} \quad (1)$$

$$S = S_1 (1 + k) \quad (59)$$

S_1 = unit soil loading due to dead load. (pounds/sq. ft.)
S_{1m} = unit soil loading due to minimum dead load (pounds/sq. ft.) to include the weight of the empty tower, the foundation and the earth fill only. It does not include insulation, platforms, piping, liquid, etc.
S_2 = unit soil loading due to overturning moment. (pounds/sq. ft.)
S_3 = total maximum unit shearing load. (pounds per lineal foot of pedestal perimeter)

$$S_3 = S_4 + S_5 \quad (81)$$

S_4 = unit shearing load due to dead load. (pounds per lineal foot of pedestal perimeter)

$$S_4 = \frac{W_s + W_a + W_p - (a_p S_{all})}{L_p} \quad (82)$$

S_5 = maximum unit shearing load due to overturning moment. (pounds/lineal foot of pedestal perimeter).
For pedestals of various shapes, the values of (S_5) are as follows:

Octagon: $S_5 = \frac{M_f}{.814d^3_p}$ (83)
Hexagon: $S_5 = \frac{M_f}{.832d^2_p}$ (83a)
Square: $S_5 = \frac{M_f}{.943d^3_p}$ (83b)
Circle: $S_5 = \frac{M_f}{.785d^3_p}$ (83c)

S_{all} = maximum allowable unit soil loading. (pounds/sq. ft.)
S_b = load on each foundation bolt. (pounds)
S_g = unit soil loading due to pull on guy wires. (pounds/sq. ft.)
S_{min} = total unit soil loading under minimum dead load conidtions. (pounds/sq. ft.)
S_t = unit stress in tower shell due to bending moment (M_t). (pounds/sq. ft.)
t = shell thickness. (feet)
u = bond stress (between concrete and reinforcing steel) per unit of area of surface of bar. (pounds)
V = velocity of wind. (miles per hour)
V_s = vertical shear load outside the critical section (see Figures 3 and 3c). (pounds)
W = total weight on soil (pounds) calculated by the following equation:

$$W = W_t + W_s \quad (3)$$

W_a = weight of auxiliary material and equipment supported by the foundation (pounds), including liquid in the tower, insulation, platforms, piping, etc. (Does not include weight of tower.)
W_h = weight of hammer. (pounds)
W_p = weight of foundation pedestal (top course). (pounds)
W_s = weight of empty tower. (pounds)
W_t = minimum dead load (pounds) which is the weight of the empty tower plus the weight of the foundation, including the earth fill on top of the base.
Z = section modulus of the base of the foundation (to be based on foundation dimensions in feet) as follows:

$$Z = \frac{I}{c} \quad (11)$$

π = 3.1416
θ = angle which guy wire makes with the vertical. (degrees)
Σ_o = sum of perimeters of reinforcing bars within the limits of the beam width (ab). (inches).

Maintenance and Trouble-Shooting Tips for Electronic Control

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ELECTRONIC control devices—ranging from specialized resistance welding controls used in metal-working industries to standard photoelectric relays (electric eyes) used for hundreds of jobs in all industries—are being worked hard in today's production battle. Electronic equipment, generally, requires less maintenance than other electric equipment since it has no moving or wearing parts. Nevertheless, to keep it in top-notch operating condition and to prevent production interruptions, it is essential that certain maintenance procedures and checks be followed and that troubles be located and remedied as quickly as possible.

This article is not intended to be an exhaustive step-by-step treatment of the maintenance of particular electronic controls but rather a "highlight" discussion of good maintenance, trouble-finding, and trouble-correcting practices on electronic controls generally.

Most of the components of electronic controls—resistors, reactors, transformers, and capacitors—are of a semi-permanent nature and are conservatively rated to give many years of service with very little maintenance. Even the electron tubes themselves, while replaceable, require inspection and test only at comparatively long intervals.

In view of these facts and the fact that electronic control sometimes will continue to function under extreme conditions of moisture, temperature, and dirt, there is frequently a tendency to neglect the simple rules of good maintenance.

First, it must be remembered that many parts of electronic controls are similar to those used in magnetic controls. Enclosing cases, bases, terminals, and wiring and conduit devices are frequently identical. Standard magnetic control devices—such as fuses, switches, and overload relays of both the instantaneous and the time-delay types—are found on many electronic panels. These devices usually perform starting or protective functions and operate infrequently. As in the case of standard magnetic control panels, this infrequent operation itself sometimes results in special maintenance problems. Detailed instructions as to the inspection and maintenance of these standard devices may be found in maintenance manuals covering this equipment.

Particular emphasis should be placed on inspection for cleanliness and the effects of vibration. Because of the high impedances used in some electronic circuits, an excessive accumulation of dust or processed material will, particularly when damp, provide parasite circuits which may interfere with proper operation. Lenses and other parts of optical systems should be wiped off frequently with a clean, soft rag.

Since many electronic panels are interconnected extensively with other apparatus, the loosening of connections or the breakage of leads through the effects of vibration may cause serious shutdowns, entailing intensive (and sometimes aggravating) "trouble shooting" before the fault is located. Vibration also tends to shorten tube life. If severe vibration is found to exist at the installation location, shock mounting of the control panels, as well as the use of stranded or extra flexible leads, may be justified.

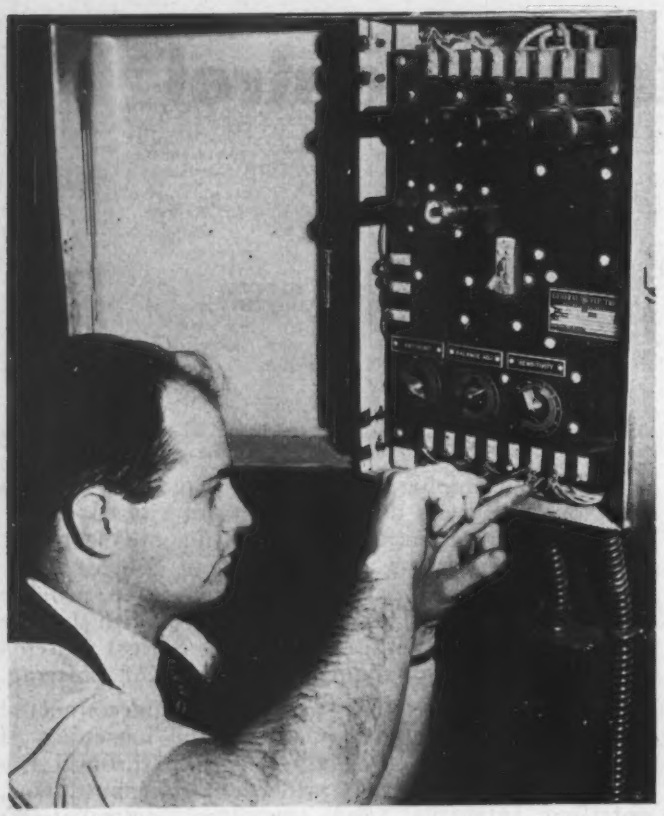
Photoelectric and other electronic controls involving mechanical components should be checked frequently to assure that the mechanical adjustments have not been disturbed. Common causes of such disturbances are bolts loosening under vibration or chain hoists and other shop equipment hitting against the equipment.

Very rarely does a modern electronic tube fail suddenly. Usually the failure is the result of a gradual loss of emission that takes place as the active cathode material is used up or flakes off. Overloading, mechanical abuse, operation at high or low filament or cathode heater voltage, and operation outside of required temperature limits all tend to shorten tube life.

Among the most prevalent causes of poor operation and short tube life are the operation of electronic panels on line voltages differing too greatly from the panel nameplate voltage, and the use of the wrong tap when a tapped-input transformer is provided. Panels usually are designed to operate satisfactorily on line voltages varying plus or minus five percent of the panel rating. If the voltage at the installation point is consistently high or low, a small auto, or booster, transformer may be used. If the line voltage fluctuates widely, a special voltage-regulating transformer may be required. Faulty heater transformers,

loose connections, and corroded socket connections also may limit the low-voltage, high-current power required for the tube cathode heater.

High-vacuum tubes and tubes filled with true gases, such as argon and xenon, may be operated



Electronic control panel subject to slight vibrations (not sufficient to require shock mountings) having periodic check to assure that screws and bolts are tight.

without difficulty over a wide ambient temperature range, but tubes using mercury vapor operate best in a more restricted ambient range. Enclosing case ventilation and other temperature-regulating means are provided for the usual industrial indoor ambient temperatures of 60 to 100° F. For low ambient temperatures, manually or thermostatically controlled strip heaters may be mounted in the case. For temperatures from 100 to 120° F., fan or forced-air cooling may be sufficient. Above this temperature, components other than the tubes may be affected also and it may be that standard equipment will be unsuitable for the installation.

Panels which use gas- or mercury-filled tubes normally are equipped with a cathode protective timer. This timer should be set for the heating period designated by the instructions accompanying each new tube. This time has been found by experience to be the minimum time permissible for reasonable tube life and must not be decreased for any reason.

During the shipment or handling of mercury-vapor-type tubes, the liquid mercury may be splashed on the elements. Therefore, when the tube is first placed in service, it is necessary to heat the tube cathode for a time with the anode lead disconnected, distilling off the splashed mercury before the anode power is applied. This requires a longer period than the usual cathode heating time; the tube instructions give the proper time.

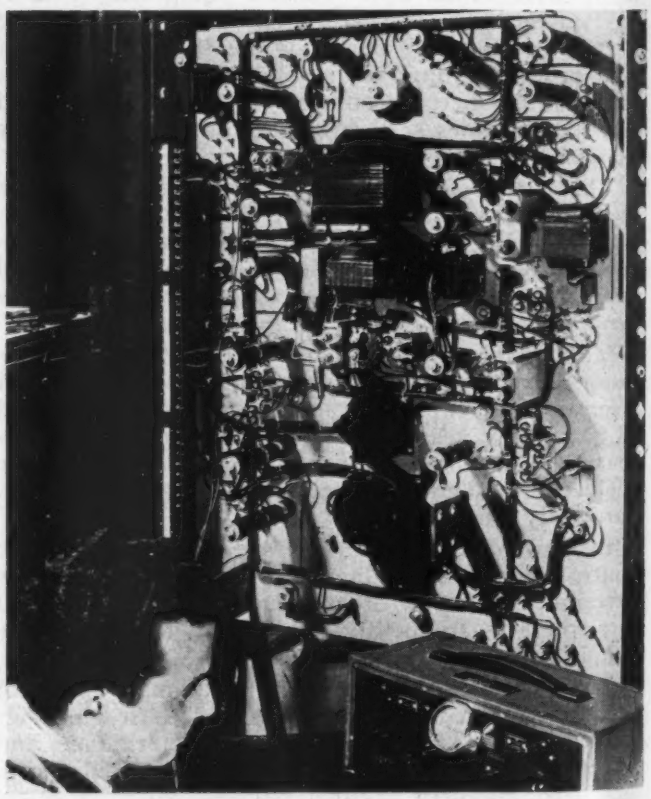
Some electronic panels are designed to use tubes on external loads. It is essential that these loads not be greater than either the average or peak rating of the tubes. Sometimes an operator will increase the anode voltage, replace coils, or alter motor pulleys or gearing to obtain a greater output, thus overloading the tubes. Since they seriously reduce tube life, such practices should be avoided.

The effects of vibration on tube life have already been considered but shocks and jars in handling tubes, particularly when they are old, can be quite detrimental. Sharp shocks, such as caused by dropping or striking the tube, if they do not actually rupture the envelope, may jar the elements out of position or even break welds or leads.

Mercury-vapor tubes must be kept upright as much as possible to keep the mercury off the elements.

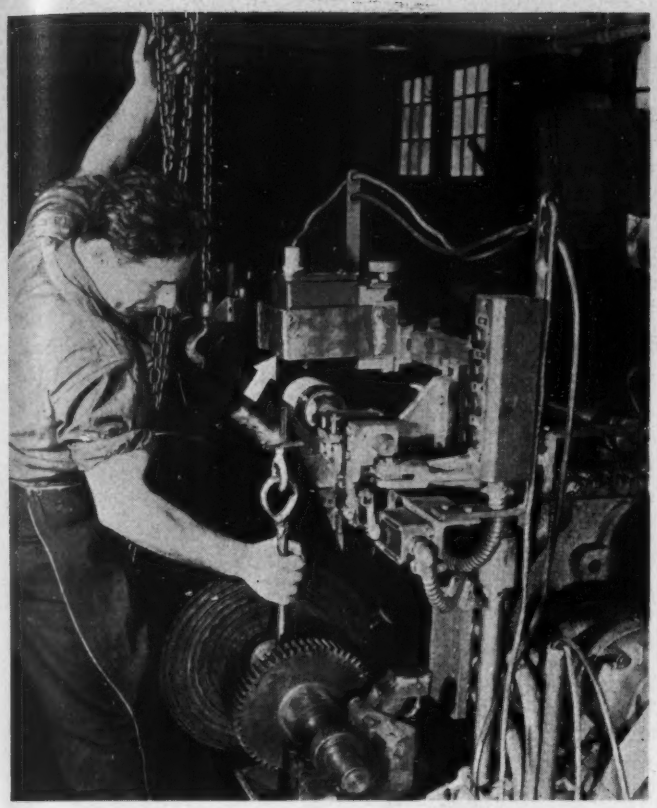
Trouble-Shooting

The best trouble-shooting tool is a clear knowledge of the operation of the panel and each part of it. If partial operation is obtained but other actions fail to occur, the trouble may be isolated to a part of the circuit.



Electronic control panel being checked with cathode-ray oscilloscope, a useful instrument for checking wave shapes when searching for faults.

Since many circuits on electronic panels have a very high impedance, meters having high impedances are very desirable in servicing the equipment. A useful tool is the radio service multimeter which has a resistance of 1000 ohms per volt or higher. For some circuits, however, an electronic meter, such as a



Photoelectric scanning heads and similar items, adjustment of which is precise and should be protected against being struck by workmen or by mobile shop equipment. Arrow points to guard placed around scanning head to prevent chain hoist from striking head and disturbing its adjustment.

vacuum-tube voltmeter of the d-c reading type or a cathode-ray oscilloscope, is essential. The cathode-ray oscilloscope, particularly when modified to read direct-current potentials, is an extremely useful device since it combines a very high impedance voltmeter with a time axis, thus making visible voltage changes much too rapid for the ordinary meter to follow. Instantaneous thyratron grid and plate potentials and other voltage waveforms may be observed easily on the oscilloscope and any incorrect operation quickly detected.

In trouble-shooting on electronic control, one should first make sure that the trouble lies in the electronic equipment. Is power available at the control panel terminals? Can the motor or other device be operated by alternate means (such as from a d-c bus by drum switch or magnetic control) if provided? Are all protective devices and interlocks outside of the panel operating properly? Has the cathode protective timer relay completed its timing cycle and applied anode power? Have mechanical adjustments been disturbed where items such as scanning heads or other mechanical components are used?

The times at which the failure occurs may be divided roughly into three: (1) when first starting a new equipment; (2) when starting after a normal shutdown; and (3) during operation.

New Equipment Fails to Start

When new electronic equipment fails to start, the cause may be a lack of correct power, incorrect or missing connections, tubes in wrong sockets, use of wrong or defective tubes, no fuses or wrong size fuse, or damage done to panel leads or parts in shipment.

Incoming power should be checked against panel nameplate. The remedy for no power, missing wires, and fuses is obvious. The position and type of tubes can be checked by referring to the wiring diagram and the panel stamping. Defective tubes and (sometimes) tubes in the wrong socket may not heat up. The glow of the hot cathode usually may be seen in glass tubes; in metal tubes the envelope becomes hot to the touch. (The envelope of metal thyratrons and ignitrons is at cathode potential. Do not touch while power is on the panel.)

Failure caused by breakage of leads or parts on panel is covered below under "Equipment Fails During Operation."

Lenses and other parts of photoelectrical optical systems should be wiped off regularly with clean, soft rag. On this machine the operator is carrying out responsibility to see that scanning head's optical system is cleaned regularly.

Equipment Fails to Operate After Shutdown

When electronic equipment does not operate after a normal shutdown, first check power, interlocks, and safety switches. The cathode heating timer relay may have failed or the anode contactor may be defective. An old tube often fails due to expansion and contraction as power is switched off or on. Filament or heater burnouts may be detected quickly by inspecting glass tubes or by feeling metal tubes for heating. Power should be removed before touching metal thyratrons and ignitrons. Sometimes an over-

loaded transformer or reactor will fail due to the expansion cycle as power is removed and applied. Here, however, warning of failure is usually given by excessive heating, the odor of the hot material, melting of the sealing compound, or smoking or charring of the insulating paper.

Failures caused by leads or parts going bad during shutdown are covered below.

Equipment Fails During Operation

If after a period of satisfactory operation, the equipment's operation quickly becomes unsatisfactory or ceases altogether, it often is possible to isolate the trouble to a specific cause by noting the exact symptoms of the failure. Power failure or a blown fuse result in an instantaneous change in the equipment's operation. An overloaded transformer, resistor, or wire is usually indicated by heat and smoke before total failure occurs. The cause of overload—whether shortcircuit, load-coil burnout, or motor-bearing failure—must be found and corrected before the equipment is again placed in service.

A failure in a tube cathode circuit permits the cathode to cool gradually over a period of seconds or even minutes. Therefore, the loss of operation may be gradual rather than sudden as in the case of power failure. However, small rectifier- and battery-operated tubes cool quickly.

If none of the above causes for failure are evident it will be necessary to go carefully through the operation of the circuit and to analyze each step. An instruction book for the particular panel or at least an elementary diagram of the circuit should be available. If the circuit is at all extensive, it is usually possible to divide it into two parts, for example, the control and power circuits of a welding control. Then it may be possible to use a meter, electronic voltmeter, cathode ray oscilloscope, or some other means to determine whether or not the control section is operating correctly as the input is varied over the normal range. Likewise, a simulated control signal may be applied to the power circuit to test that half.

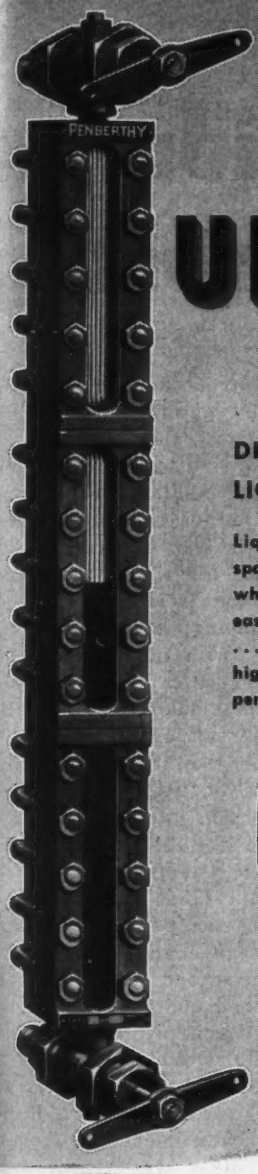
In a similar manner, each part of the circuit can be further subdivided until the faulty circuit or part is found. With a clear knowledge of each part of the circuit, this procedure can be carried out quite rapidly. It is a good idea to check the operation of panels while they are operating correctly and to record voltages found and cathode ray traces seen between specific points. In this way, the differences found in a defective panel will be immediately evident, and the trouble-shooting will take much less time.

If trouble is recurring in certain parts of the circuit, the manufacturer should be notified. Quite often a more permanent solution may be offered or the assistance of the manufacturer's design engineers may be obtained to suggest a cure. Sometimes, slight modifications in the equipment may be proposed to provide more desirable characteristics for the particular installation. In every case, complete information from the panel nameplate as well as a description of the part and the trouble found should be given to the manufacturer so that assistance may be rendered quickly and effectively.

Electronic control equipment being checked for line voltage which should correspond to panel nameplate rating or with variation plus or minus 5 percent of marked value. Front view showing electrician checking voltage and familiarizing himself with voltages that exist between various points on panel so that if trouble is encountered he will be able to locate it quickly.

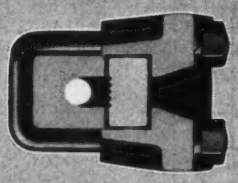
Electronic tube being checked in tube tester. Tubes in control apparatus should be checked regularly and replaced when found defective. It is recommended that spare set of tubes be kept handy at all times.

QUALITY UNCOMPROMISED



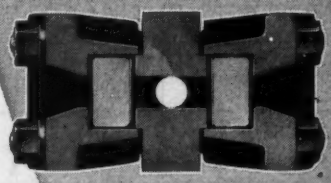
PENBERTHY
Reflex
DROP FORGED STEEL LIQUID LEVEL GAGES

Liquid shows black—empty space shows white. Preferred wherever liquid level must be easily and positively visible . . . and when liquids are under high pressure or at high temperature.



PENBERTHY
Transparent
DROP FORGED STEEL LIQUID LEVEL GAGES

Used to observe color and density of liquids under high pressures, and/or temperatures. Construction is exceptionally rugged . . . similar to Reflex types.



Penberthy Liquid Level Gages

ALL PENBERTHY GAGES CONFORM WITH A. P. I.—A. S. M. E. REQUIREMENTS

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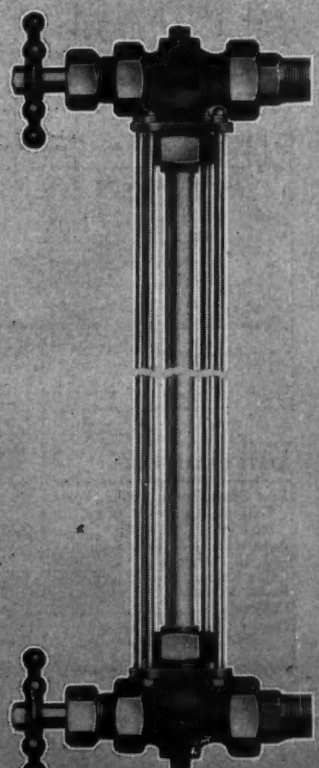
Water shows black—steam shows white. U-bolt construction is strongest and simplest to service. Glass replaced by simply removing nuts on face of gage . . . unnecessary to work between gage and boiler.



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DROP FORGED STEEL LIQUID LEVEL GAGES

Made of Chromium-molybdenum alloy temperature-resisting steel, extra heavy throughout. Stainless steel trimmed. Tubular glass type gages also available in various other metals suitable for practically all conditions.

PENBERTHY INJECTOR CO.

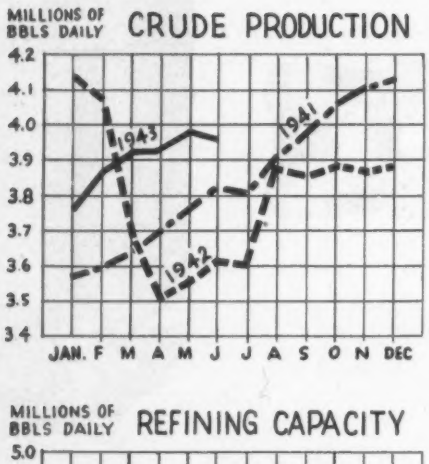
DETROIT, MICHIGAN • Canadian Plant: Windsor, Ontario

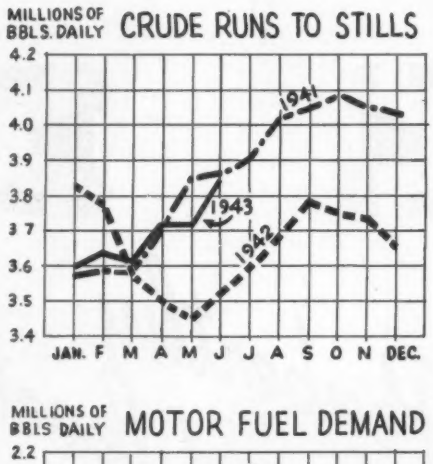
PENBERTHY PRODUCTS

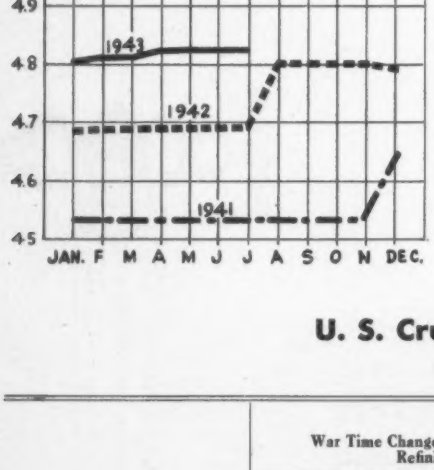
Record Crude Production and Runs Required to Meet Huge

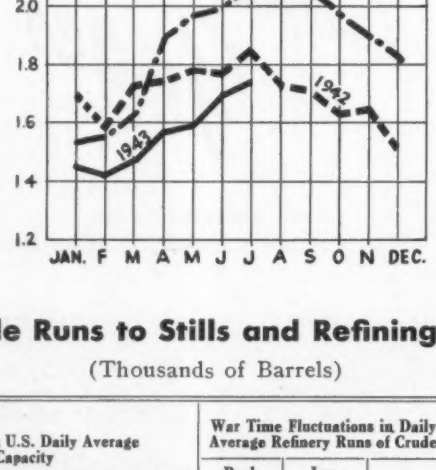
United States wells and refineries turn out unprecedented volumes of oils in first half of 1943 in meeting heavy demands, as only limited supplementary supplies are available in form of withdrawals from storage and imports of crude and fuel oil

L. J. LOGAN









ALTHOUGH participation in the war has forced curtailment of the normal use of gasoline, heating oil, and other products, there have been sharp increases in consumption of petroleum products for military purposes and for industrial purposes furthering the prosecution of the war. Consequently, the total demand for all oils has shown no great decline from former levels and now is running very close to the year-ago trend, with further gains in prospect for the latter half of the year.

In the first quarter of 1943, the total demand for all oils was about 9 percent smaller than that in the corresponding period of 1942, which reflected a brief extension into 1942 of the record demand of late 1941. However, a better comparison was made by the second quarter of 1943, as total demand for all oils during the period apparently was only between 1 and 2 percent smaller than in the second quarter of 1942. This year's second quarter reflected remarkably effective adjustment of the industry's facilities and operations to the conditions imposed by the war, whereas last year's second quarter reflected the full and heavy impact of tanker sinkings and other war-created problems, which the industry and the government still had only begun to solve.

Normally, reduced demand, such as that which was recorded for the first half of this year, would have resulted in similarly curtailed production and refinery processing of oil. But abnormal situation with regard to imports and storage prevented normal courses for production and refinery runs, and both reached unprecedented January-June

U. S. Crude Runs to Stills and Refining Capacity

(Thousands of Barrels)

STATE OR DISTRICT:	War Time Changes in U.S. Daily Average Refining Capacity						War Time Fluctuations in Daily Average Refinery Runs of Crude			Crude Runs in First 6 Months, 1942-1943				
	Available			Percent Used			Peak Before U.S. Entry in War: Oct., 1941	Low After U.S. Entry in War: May, 1942	Current Data: June, 1943	Total Amount		Daily Average		
	Dec., 1941	May, 1942	June, 1943	Dec., 1941	May, 1942	June, 1943				1942	1943	1942	1943	Percent Difference
East Coast, Texas, Inland, Texas Gulf, La. Gulf, Ark. & La. Inland	2,313	2,383	2,444	85.7	63.7	74.4	2,127	1,498	1,819	313,751	305,552	1,733	1,688	— 2.5
Appalachian	166	174	177	96.4	91.4	87.0	147	158	154	28,151	27,967	155	154	— 0.6
Ind., Ill., Ky., etc.	752	784	824	95.7	99.2	87.2	734	735	719	128,178	129,500	708	715	+ 0.9
Okla., Kansas, Mo.	413	418	416	73.6	86.1	82.9	368	359	345	62,930	61,631	347	340	— 2.0
Rocky Mountain	136	138	147	54.4	65.2	67.3	94	91	99	16,757	16,586	92	91	— 1.0
California	787	787	817	77.3	78.3	89.2	618	605	729	102,747	128,134	567	707	+24.6
Total United States	4,567	4,684	4,825	90.1	75.2	80.1	4,088	3,446	3,865	652,514	669,370	3,605	3,698	+ 2.5

High Refinery Military Needs

proportions. To an increased extent, it has been necessary this year to meet the requirements direct from domestic wells and refineries, with normal supplementary supplies of crude and fuel oil from foreign countries greatly curtailed; while it has not been possible to fall back on storage as a supplementary source of supply, inasmuch as stocks have been drawn down to critically low levels. In fact, it has been found expedient this year to endeavor to add to stocks of crude oil as a matter of safety, and actually, in the first 6 months, production was stepped up even above current needs to permit the addition of 7,000,000 barrels to storage. This re-building of storage in conjunction with curtailment of imports forced crude production artificially high. Similarly, crude runs to stills were forced exceptionally high by reduction of imports of fuel oil and by the inability to draw heavily as in 1942 on stocks of refined products.

These combinations of extraordinary circumstances explain why it has been that in the face of some curtailment of the demand, both crude oil production and refinery runs of crude were greater in the first 6 months of 1943 than in the corresponding months of any other year. The January-June production and refinery runs for the past three years have been as herewith indicated.

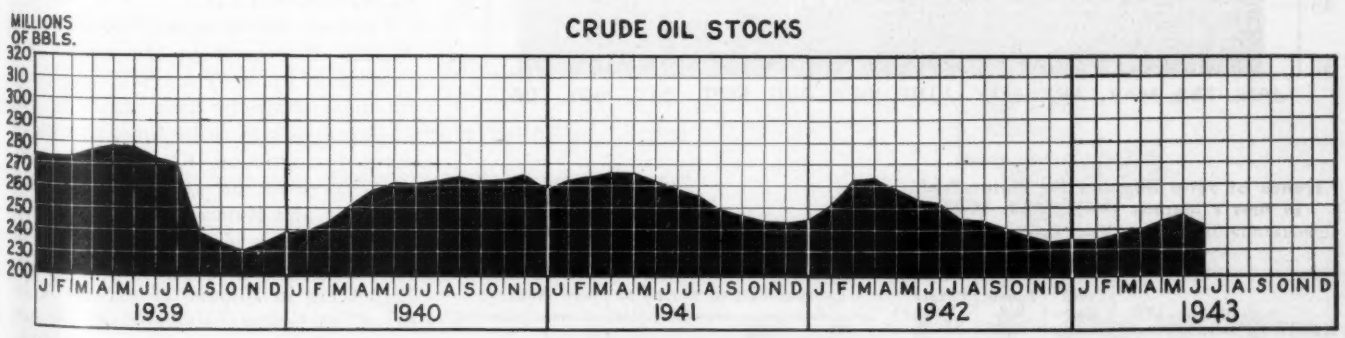
	First 6 Months (Thousands of Barrels)		
	1941	1942	1943
Crude Oil Production	667,338	680,536	706,881
Crude run to stills...	668,663	652,514	669,370

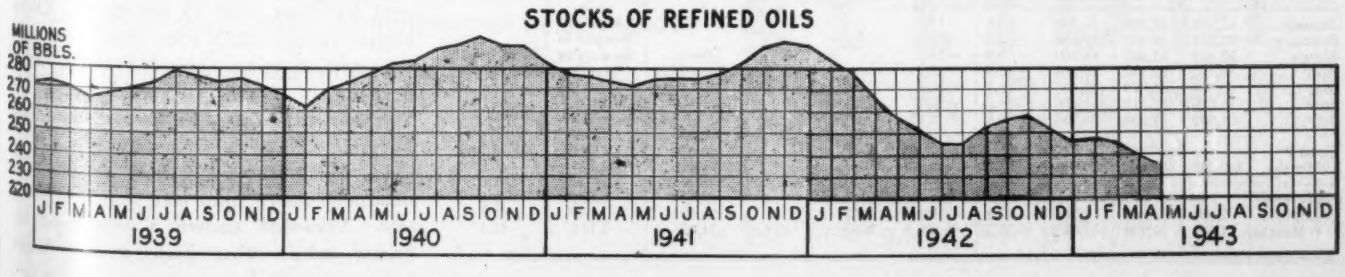
Production for the January-June period, 1943, was nearly 4 percent greater than that in the first half of 1942, and Crude Oil output is due to continue materially above the 1942 trend. During June, 1943, it was 9.6 percent greater than in June, 1942. And for July, 1943, the Bureau of Mines estimated that the daily average supply of domestic oil required to meet the market demand would be 6 percent higher than the actual for July, 1942. The further sharp rise in demand that is expected for the third quarter as compared with the second quarter will have to be met by additional increases in productoin or by withdrawals from storage. However, crude oil stocks were reduced 5,000,000 barrels during June and were down by

United States Crude Oil Production

(Thousands of Barrels)

STATE OR DISTRICT	War Time Fluctuations in Daily Average Production: Peak Before U. S. Entry in War: December, 1941	War Time Fluctuations in Daily Average Production: Low After U. S. Entry in War: April, 1942	War Time Fluctuations in Daily Average Production: Current Data: June, 1943	Production n First is Months, 1942-1943: Total Amount 1942	Production n First is Months, 1942-1943: Total Amount 1943	Daily Average 1942	Daily Average 1943	Percent Difference
Arkansas	74.3	71.6	74.7	13,233	13,250	73.1	73.2	+ 0.1
California	631.9	637.5	770.4	114,511	139,985	632.7	773.4	+22.2
Colorado	6.1	5.7	7.0	1,057	1,181	5.8	6.5	+12.0
Illinois	397.8	301.6	216.7	57,871	41,865	319.7	231.3	—27.6
Indiana	18.6	19.8	13.9	3,557	2,678	19.7	14.8	—24.8
Kansas	256.7	249.8	296.0	45,100	54,889	249.2	303.3	+21.7
Kentucky	12.7	11.9	21.1	2,114	3,556	11.7	19.6	+67.5
Louisiana	347.4	306.8	328.5	57,860	60,513	319.7	334.4	+ 4.5
North Louisiana	139.3	75.3	85.4	13,542	15,379	74.8	85.0	+13.6
South Louisiana	208.1	231.5	243.1	44,318	45,134	244.9	249.4	+ 1.8
Michigan	56.8	62.5	56.9	10,357	10,510	57.2	58.1	+ 1.5
Mississippi	70.5	96.2	53.5	15,862	10,013	87.6	55.3	—36.8
Montana	22.0	22.0	20.8	3,980	3,566	22.0	19.7	—10.4
Nebraska	5.1	3.9	2.1	701	393	3.9	2.2	—43.5
New Mexico	112.2	67.3	97.0	15,228	17,497	84.1	96.7	+14.9
New York	15.1	15.3	14.4	2,692	2,557	14.9	14.1	— 5.3
Ohio	9.9	10.6	9.2	1,771	1,584	9.8	8.8	—10.2
Oklahoma	427.6	389.6	334.7	71,615	61,393	395.6	339.2	—14.2
Pennsylvania	49.3	52.7	45.4	9,015	8,145	49.8	45.0	— 9.6
Texas	1,532.3	1,081.0	1,504.0	236,694	255,440	1,307.7	1,411.2	+ 7.9
East Texas Field	386.2	225.4	337.1	57,296	59,538	316.5	328.9	+ 3.9
Rest of East Texas	86.1	78.7	123.8	15,591	19,590	86.1	108.2	+25.6
North Texas	137.1	130.5	132.2	26,306	24,368	145.4	134.6	— 7.4
West Texas	302.4	185.8	229.8	42,017	39,269	232.2	216.9	— 6.5
Texas Panhandle	92.1	83.5	90.1	15,703	16,231	86.7	89.6	+ 3.3
Gulf Coast, Upper	303.2	227.5	381.8	47,833	62,868	264.2	347.3	+31.4
Gulf Coast, Lower	126.9	82.6	135.1	17,868	21,000	98.7	116.0	+17.5
Southwest Texas	78.2	48.0	57.6	10,636	9,505	58.8	52.5	—10.7
South Central Texas	20.1	19.0	16.5	3,444	3,071	19.1	16.9	—11.5
West Virginia	9.8	10.4	9.2	1,787	1,690	9.9	9.3	— 6.0
Wyoming	82.2	85.4	92.3	15,499	16,167	85.6	89.3	+ 4.3
Others	.2	.2	.....	32	9	0.1	0.0	.....
Total United States	4,138.5	3,501.8	3,968.6	680,536	706,881	3,759.8	3,905.4	+ 3.8



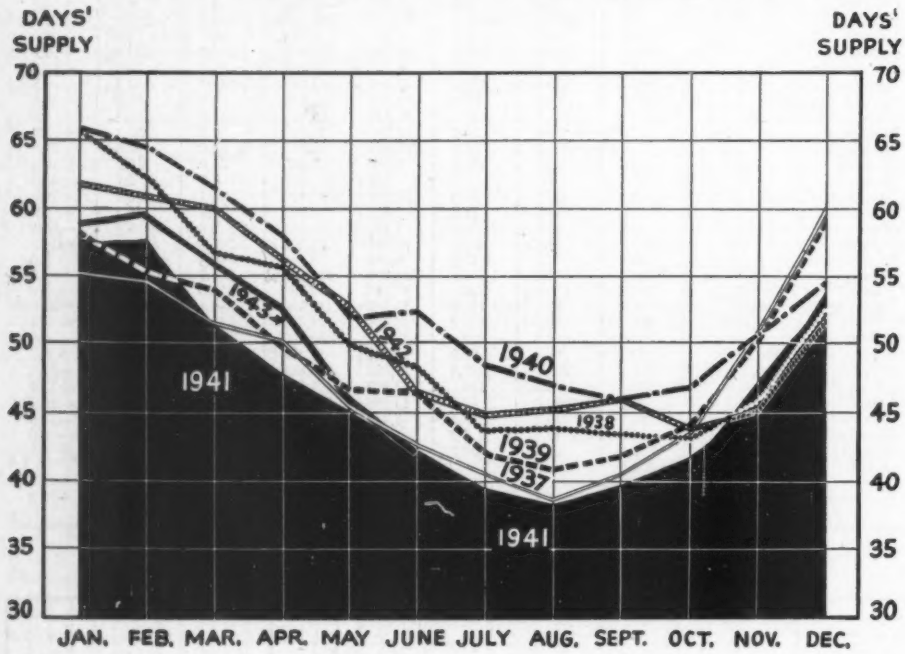


Fluctuations in Crude Stocks, by Grade or Origin, Since Pearl Harbor

(Thousands of Barrels)

GRADE OR ORIGIN	Outbreak of War for U.S. Dec. 13, 1941	High for 1942-1943 (Mar. 28, 1942)	Low for 1942-1943 (Dec. 12, 1942)	Latest Data (July 3, 1943)	Change from Mar. 28, 1942	Change from Dec. 12, 1942
Pennsylvania Grade	3,633	3,431	3,054	2,656	— 775	— 398
Other Appalachian	1,529	1,522	1,356	1,513	— 9	+ 157
Lima-Michigan	1,233	1,549	1,208	1,137	— 412	— 71
Illinois-Indiana	18,243	19,337	9,494	12,570	— 6,767	+3,076
Arkansas	2,591	2,977	2,068	2,625	— 352	+ 557
Kansas	7,400	7,696	6,898	8,588	+ 892	+1,690
Louisiana	12,348	13,669	12,732	14,966	+ 1,297	+2,234
Northern	3,849	4,223	4,745	5,359	+ 1,136	+ 614
Gulf Coast	8,499	9,446	7,987	9,607	+ 161	+1,620
Mississippi	2,202	2,445	1,174	1,288	— 1,157	+ 114
New Mexico	6,781	7,510	5,622	7,045	— 465	+1,423
Oklahoma	51,562	50,513	40,111	37,895	—12,618	—2,216
Texas	81,676	96,123	102,130	103,554	+ 7,431	+1,424
East Texas	20,549	23,677	24,468	20,984	— 2,693	—3,484
West Texas	18,070	23,961	24,252	25,607	+ 1,646	+1,355
Gulf Texas	23,935	25,889	28,388	30,534	+ 4,645	+2,146
Other Texas	19,122	22,596	25,022	26,429	+ 3,833	+1,407
Panhandle	.....	.....	4,670	5,646	.....	+ 976
North	.....	.....	7,491	6,862	.....	— 629
South	.....	.....	4,879	5,261	.....	+ 382
Other	.....	.....	7,982	8,660	.....	+ 678
Rocky Mountain	16,267	16,628	13,934	13,468	— 3,160	— 466
California	34,574	38,454	31,965	33,536	— 4,918	+1,571
Foreign	2,644	1,354	150	86	— 1,268	— 64
Total Gasoline-bearing in U. S.	242,683	263,208	231,896	240,927	—22,281	+9,031
Heavy in California	10,128	11,336	10,607	9,997	— 1,339	— 610

Days' Supply of Motor Fuel in Storage in United States at End of Month, on Basis of Demand in Succeeding Month



Trends of Total Demand for Motor Fuel in First 7 Months 1941, 1942, 1943

(Thousands of Barrels; Data from Bureau of Mines.)

MONTH	1941 (Actual)	1942 (Actual)	1943 (Forecasts)	Percent Diff. '41-'43	Percent Diff. '42-'43
January	47,389	52,192	44,800	— 5.4	—14.1
February	43,254	44,593	39,700	— 8.2	—10.9
March	50,498	53,493	45,600	— 9.6	—14.7
April	56,682	52,162	47,100	—16.9	— 9.7
May	60,895	55,079	49,400	—18.8	—10.3
June	59,622	53,319	51,100	—14.2	— 4.1
July	64,509	57,654	54,300	—15.8	— 5.8
Total 7 Months	382,849	368,492	332,000	—13.2	— 9.9
Daily avge: July	2,081	1,860	1,751	—15.8	— 5.8
7 Months	1,806	1,738	1,566	—13.2	— 9.8

U. S. Stocks of Motor Fuel at End of June in Recent Years

(Actual and in Terms of Days' Supply)

YEAR	Stocks, June 30, (Thousands of Bbls.)	Daily Average Demand in Succeeding Month (Thousands of Bbls.)	Days' Supply Represented by June 30 Stocks
1937	73,866	1,739	42.4
1938	80,676	1,669	48.3
1939	81,144	1,745	46.5
1940	93,276	1,792	52.0
1941	88,646	2,081	42.5
1942	86,651	1,860	46.5
1943	74,328	1,751	42.4

the end of that month to about 240,000,000 barrels, or 12,000,000 barrels lower than a year previously, and only about 10,000,000 barrels above the 20-year low of late 1939, indicating that any further large withdrawals from stocks might cause shortages in some districts.

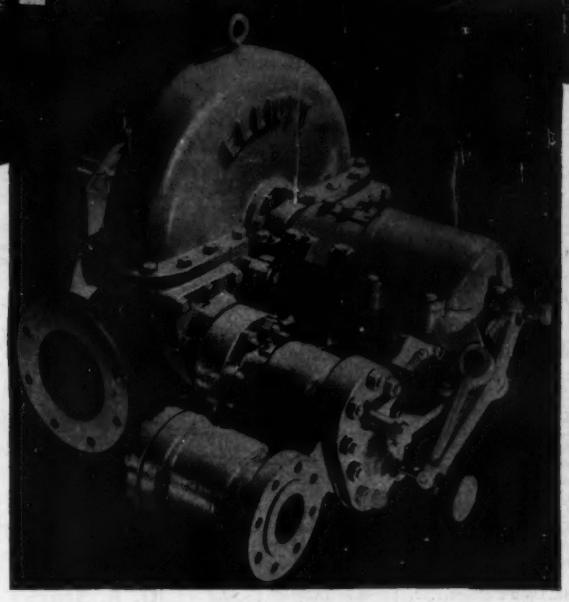
Crude oil stocks currently are at about the same level as when Pearl Harbor was attacked. They climbed sharply after Pearl Harbor, when tanker sinkings came, and they now are 22,000,000 barrels lower than the high that they reached in the spring of 1942, but they were drawn upon heavily in late 1942 and approached their 20-year low, and are at present only 9,000,000 barrels above that late-1942 low. Between January 1 and July 1 this year United States crude oil stocks were increased about 7,000,000 barrels, and most districts contributed toward the gain, exceptions having included Oklahoma, which took out over 2,000,000 barrels, East Texas, which withdrew 3,500,000, North Texas, which took out over 500,000, and the Rocky Mountain and Pennsylvania districts, each of which withdrew nearly 500,000 barrels. While Illinois formerly was furnishing crude from storage, it added 3,000,000 barrels in the first half of this year.

While United States crude oil production was 4 percent greater in the first half of 1943 than in the like period of 1942, there have been increases in some districts, while decreases have occurred in other areas, in reflection of changes in demand geographically, in meeting war needs. In response to heavy demand in the Pacific, California produced 22 percent more oil in the first half of this year than in the similar period of last year. The Rocky Mountain states, too, have registered increases: 12 percent for Colorado and 4 percent for Wyoming, while Montana showed a 10 percent decrease.

Demand has been very strong in the Middle West and in the upper Mid-Continent, but only a few of the states in those districts have had the producing ability to come forward with increased production. Kentucky's production has been 67 percent larger than last year and Kansas 22 percent higher, while Michigan records a 1.5 percent increase. Decreases in District 2 included 27 percent in Illinois, 25 percent in Indiana, 43 percent in Nebraska, 10 percent in Ohio, and 14 percent in Oklahoma. In the East, too, decreases were the rule, having included those of 5 percent in New York, 9 percent in Pennsylvania, and 6 percent in West Virginia.

In the Southwest, some districts have produced more than last year and some less. Arkansas shown a fractional increase, while other gains include those

ELLIOTT *Mechanical Drive* TURBINES



Unfailing power

FOR PUMP ROOMS

They have what refineries need, these tough turbines by Elliott. The wartime load is heavy enough to put wrinkles in the brow of any refinery engineer — but as one of them said recently — "If all my equipment was as dependable as my Elliott turbines, I'd have a lot less to worry about."

Judging by the rate at which refineries order these Elliott turbines, they are put to work on all kinds of drives, everywhere, indoors or out. They are markedly adaptable — can be powered with steam or natural gas, can be supplied with built-in reduction gears, need the minimum of maintenance, and all in all give a character of service that refinery men value highly.

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H-670

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of 14 percent for North Louisiana, 2 percent for South Louisiana, 15 percent for New Mexico, 8 percent for Texas as a whole, 4 percent for the East Texas field, 25 percent for the rest of East Texas, 3 percent for the Texas Panhandle, 31 percent for the upper Texas Gulf Coast, 17 percent for the lower Texas Coast. Decreases have included 37 percent in Mississippi, 7 percent in North Texas, 6 percent in West Texas, 10 percent in Southwest Texas, 11 percent in South Central Texas.

Runs to Stills

Crude oil run to stills in the first half of 1943 was 2.5 percent greater than in the initial half of 1942. This increase is accounted for by a 25-percent stepping up of plant operations in California and a 1-percent increase in the Middle West. Partially offsetting those increases have been decreases of 2.5 percent in the combined East-Coast Southwestern districts, 0.5 percent in the Appalachian region, 2 percent in Oklahoma-Kansas and 1 percent in the Rocky Mountain states. Runs averaged 3,865,000 barrels per day during June, 1943, and were within about 200,000 barrels of the all-time peak of 4,088,000 barrels reached in October, 1941. The current runs are more than 400,000 barrels per day higher than the low reached in the spring after Pearl Harbor, giving evidence of the restoration of operations on the East Coast and Gulf Coast as well as the stepping up of runs in California. Refineries were utilizing 80 percent of capacity in June, compared with 90 percent of a smaller capacity when runs were at their all-time peak in December, 1941.

Although crude runs to stills were 2.5 percent greater in the first half of 1943 than in the like period of 1942, production of gasoline was down about 9 percent, in line with a similar decrease in demand. In April, 1943, the yield of gasoline was only 35.3 percent of the barrel of crude, compared with a

War Time Changes in Refinery Yields of Major Products, By Districts

Percent Yield from Barrel of Crude in April

REFINING DISTRICT	April, 1941	April, 1942	April, 1943
Gasoline:			
East Coast, Texas, Louisiana, Arkansas	42.8	36.4	35.5
Appalachian	47.0	42.2	37.2
Ind., Ill., etc.	50.8	49.1	41.6
Okla., Kansas, Mo.	51.4	49.4	39.3
Rocky Mountain	48.2	45.3	42.5
California	32.7	31.3	25.8
Total United States	43.7	39.9	35.3
Kerosene:			
East Coast, Texas, Louisiana, Arkansas	6.6	5.8	6.9
Appalachian	6.2	6.5	7.5
Ind., Ill., etc.	4.8	6.5	5.8
Okla., Kansas, Mo.	6.8	7.5	8.8
Rocky Mountain	2.8	1.8	2.7
California	1.6	1.2	1.0
Total United States	5.4	5.3	5.6
Gas Oil and Distillate:			
East Coast, Texas, Louisiana, Arkansas	15.0	15.7	15.7
Appalachian	8.0	10.5	13.3
Ind., Ill., etc.	9.7	11.4	15.5
Okla., Kansas, Mo.	10.4	12.7	15.2
Rocky Mountain	8.5	11.3	10.2
California	14.7	10.5	13.5
Total United States	13.2	13.4	14.9
Residual Fuel Oil:			
East Coast, Texas, Louisiana, Arkansas	23.1	28.5	28.1
Appalachian	14.4	17.0	19.5
Ind., Ill., etc.	20.2	20.7	26.9
Okla., Kansas, Mo.	18.1	18.5	21.5
Rocky Mountain	21.4	26.4	26.4
California	40.7	45.0	46.2
Total United States	24.6	28.1	30.5
Lubricating Oil:			
East Coast, Texas, Louisiana, Arkansas	2.9	3.8	3.2
Appalachian	12.4	12.2	9.8
Ind., Ill., etc.	1.6	1.8	1.6
Okla., Kansas, Mo.	3.2	3.4	4.1
Rocky Mountain	0.4	1.2	0.6
California	1.9	1.3	1.2
Total United States	2.8	3.3	2.8

Production of and Indicated Demand for Petroleum and Products (Not Considering Imports in 1942 and 1943)

Based on data from Bureau of Mines (thousands of barrels)

ITEM	JUNE 1941	JUNE 1942	JUNE ‡1943	JUNE Percent Change 1942-1943	FIRST 6 MONTHS 1941	FIRST 6 MONTHS 1942	FIRST 6 MONTHS ‡1943	FIRST 6 MONTHS Percent Change 1942-1943
All Oils								
Production:								
Crude	115,027	108,595	119,058	+ 9.6	667,338	680,536	706,881	+ 3.8
Natural Gasoline	5,095	6,558	7,000	+ 6.7	29,621	40,809	43,418	+ 6.3
Benzol	274	.....	†	.....	1,749	597	†	.....
Total Production	120,396	115,153	126,058	+ 9.4	698,708	721,942	750,299	+ 3.9
Imports	6,182	.....	.....	.....	43,374	.....	.....	.....
Change in Stocks	—3,125	—9,224	—5,000	.....	—11,456	—36,581	—10,405	.....
Demand	129,703	*124,377	*131,058	+ 5.3	753,538	*758,523	*760,704	+ 0.2
Crude Oil								
Production	115,027	108,595	119,058	+ 9.6	667,338	680,536	706,881	+ 3.8
Imports	4,332	.....	.....	.....	22,014	.....	.....	.....
Change in Stocks	—3,036	—3,156	—3,865	.....	—5,004	+4,537	+7,331	+61.5
Demand	122,395	*111,751	*122,923	+ 9.9	694,356	*675,999	*699,550	+ 3.4
Gasoline								
Production	55,136	44,250	46,688	+ 5.5	313,297	295,854	269,702	— 8.8
Imports	.....	.....	.....	.....	1	.....	.....	.....
Change in Stocks (Finished Gasoline)	—3,067	—7,381	—4,475	.....	+4,552	—6,333	—2,428	.....
Demand	58,203	*51,631	*51,163	— 0.9	308,746	*302,187	*272,130	— 9.9
Kerosene								
Production	5,218	4,929	6,330	+28.4	35,901	34,562	36,709	+ 6.2
Imports	.....	.....	.....	.....	43	.....	.....	.....
Change in Stocks	+1,188	+1,064	+1,958	.....	+97	—102	—2,012	.....
Demand	4,030	*3,865	*4,372	+13.1	35,847	*34,664	*38,721	+11.7
Distillate Fuel Oil								
Production	14,697	15,210	15,409	+ 1.3	92,072	90,958	99,399	+ 9.2
Transfers from Crude	210	195	250	+28.2	1,220	1,174	1,450	+23.5
Imports	211	.....	.....	.....	1,887	.....	.....	.....
Change in Stocks	+2,869	+2,220	+1,492	.....	—4,571	—17,425	—11,088	.....
Demand	12,249	*13,185	*14,167	+ 7.4	99,750	*109,557	*111,937	+ 2.1
Residual Fuel Oil								
Production	27,882	28,352	33,823	+19.2	164,125	173,517	198,020	+14.1
Transfers from Crude	1,070	1,610	1,800	+11.8	4,802	10,193	11,209	+ 9.9
Imports	2,083	.....	.....	.....	15,669	.....	.....	.....
Change in Stocks	+469	—2,047	—690	.....	—8,287	—16,854	—4,675	.....
Demand	30,566	*32,009	*36,313	+13.4	192,883	*200,564	*213,904	+ 6.6

* Indicated demand not considering imports. † Included with natural gasoline. ‡ Bureau of Mines for first 4 months; May and June estimated with aid of A.P.I. weekly reports.

U. S. Stocks of Major Petroleum Products at End of June, by Districts

(Thousands of Barrels)

REFINING DISTRICT	June 30, 1941	June 30, 1942	June 30, 1943	Percent Change From 2 Years Ago	Percent Change From 1 Year Ago
Gasoline: (Finished and Unfinished)					
East Coast, Texas, Louisiana and Arkansas	43,076	41,638	31,266	— 27.4	— 24.9
Appalachian	3,292	2,676	2,354	— 2.8	— 12.0
Indiana, Illinois, Kentucky, etc.	17,786	16,515	16,466	— 7.4	— 0.2
Oklahoma, Kansas, Missouri	7,595	7,722	6,280	— 17.3	— 18.6
Rocky Mountain	2,036	2,294	1,842	— 9.5	— 19.7
California	16,057	16,672	20,653	+ 28.6	+ 23.8
Total United States	89,842	87,517	78,861	— 12.2	— 9.8
Gas Oil and Distillate:					
East Coast, Texas, Louisiana and Arkansas	21,673	15,075	14,054	— 35.1	— 6.7
Appalachian	376	527	1,027	+173.1	+ 94.8
Indiana, Illinois, Kentucky, etc.	3,774	3,663	4,896	+ 29.7	+ 33.6
Oklahoma, Kansas, Missouri	1,397	1,444	1,862	+ 33.2	+ 28.9
Rocky Mountain	296	306	348	+ 17.5	+ 13.7
California	10,853	11,486	12,130	+ 11.7	+ 5.6
Total United States	38,369	32,501	34,317	— 10.5	+ 5.5
***Residual Fuel Oil:**					
East Coast, Texas, Louisiana and Arkansas	19,180	16,221	12,455	— 35.0	— 23.2
Appalachian	539	613	562	+ 4.2	— 8.3
Indiana, Illinois, Kentucky, etc.	3,568	3,184	3,216	— 9.8	+ 1.0
Oklahoma, Kansas, Missouri	2,066	1,516	1,624	— 21.3	+ 7.1
Rocky Mountain	640	671	646	+ 0.9	— 3.7
California	55,024	44,136	38,613	— 29.8	— 12.5
Total United States	81,017	66,341	57,116	— 29.5	— 13.9

* Exclusive of heavy crude in California.

NO. 7 OF A SERIES

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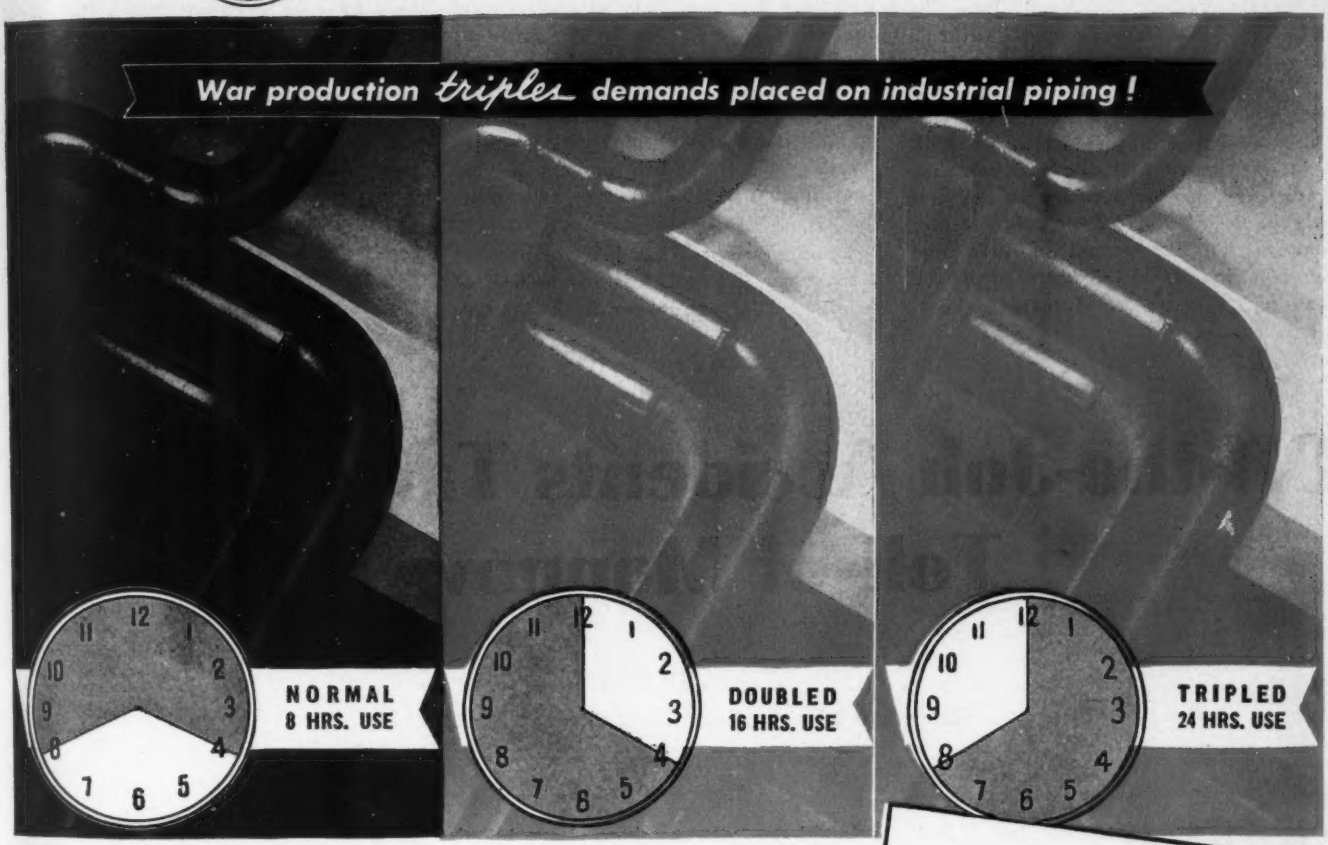

'ROUND the clock, war-time operation for 24 hours a day instead of the normal 8 hours period *triples* the wear of oil, gas, power, chemical, heating, air, refrigeration and marine piping today.

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yield of 39.9 percent in April, 1942, and the normal yield of 43.7 percent in April, 1941. Through the change in yields and lowering of production, surpluses of gasoline have been avoided, and the stocks of that product are fairly in line with curtailed consumption. Finished and unfinished gasoline in storage June 30, 1943, totaled 78,861,000 barrels, or 9.8 percent less than the 87,517,000 barrels on hand June 30, 1942. All districts except California have reduced inventories.

While production of gasoline has been lowered, it has been necessary to increase domestic production of both light and heavy fuel oils and kerosine. The production of kerosine in the first half of 1943 was 6.2 percent greater than in the like period of 1942, and there was a 2,000,000 barrel draft on storage, indicating an increase of nearly 12 percent in the demand for kerosine. Yields of kerosine at the refineries have been only slightly increased.

Production of distillate fuel oil was 9 percent larger in the first half of 1943 than in the like period of 1942, but 6,000,000 barrels less came from storage, indicating that demand for this product was about 2 percent greater this year than last year. Stocks of light fuel oil have been kept in line with the slightly larger demand. On June 30 they were 5.5 percent above a year previously. The refinery yield of gas oil and distillate was up to 14.9 percent in April, 1943, from 13.4 percent a year previously and 13.2 percent two years before.

Residual fuel oil has been in particularly great demand, and production of it was 14 percent larger from January to June this year than in the like period last year. However, it was not possible to take nearly as much from storage, the withdrawal having totaled less than 5,000,000 barrels, against one of nearly 17,000,000 in the first half of 1942. Consumption was held down to some extent, meanwhile by the expedient of converting some oil burners to other fuels. These figures indicate a normal increase over last year in the demand for residual fuel oil, although figures are not available on imports to reveal the demand exactly. The yield of residual fuel oil for the United States was stepped up as of April, 1943, to 30.5 percent, compared with 28.1 percent in April, 1942, and 24.6 percent in April, 1941. Stocks of residual fuel oil now are 14 percent lower than a year ago and 30 percent lower than 2 years ago.

Off-the-Job Accidents Take Heaviest Toll of Manpower

NED H. DEARBORN
Executive Vice President, National Safety Council

THEY were not at work, but 26,500 American workers were killed by accidents during 1942.

They were killed on cellar stars, in bath rooms, driving cars, crossing streets. They died "accidental" deaths on fishing trips and while swimming. They shot themselves cleaning "unloaded" guns. They drank what they did not think was poison.

They were killed in almost every conceivable way and in almost every imaginable situation, except at their benches and machines.

With absenteeism such a serious production and personnel problem, employers have become acutely aware that there are two kinds of accidents—those suffered on the job and those suffered off the job. Keeping books on time lost from accidents in those two categories measures the problem and indicates where added emphasis is needed.

No split bookkeeping is needed, however, to see the result. Regardless of where an accident strikes a man down, time is lost from work. Hence, the occurrence becomes a very real production, personnel and safety problem to employers.

I said that off-the-job accidents killed 26,500 workers last year.

Check the following figure and the comparison it makes with that off-the-job total: Accidents on the job killed 18,500 workers during 1942. Simple arithmetic shows that 8,000 more workers were killed in accidents off the job than were killed on the job.

In addition to accident fatalities, 2,200,000 workers suffered non-fatal, time-losing accidents off the job, 300,000 more than the total who suffered non-fatal, time-losing accidents on the job.

Those figures pose a problem to management: What to do about accidents to workers which occur while they are away from work—accidents which are robbing war production of tens of millions of man-hours of victory-hurrying work?

By supervision, rules, regulations, discipline and mechanical guarding the on-the-job problem can be controlled. We all know that. But what can an employer say or do about how safely or dangerously a worker conducts himself while he is on his own time?

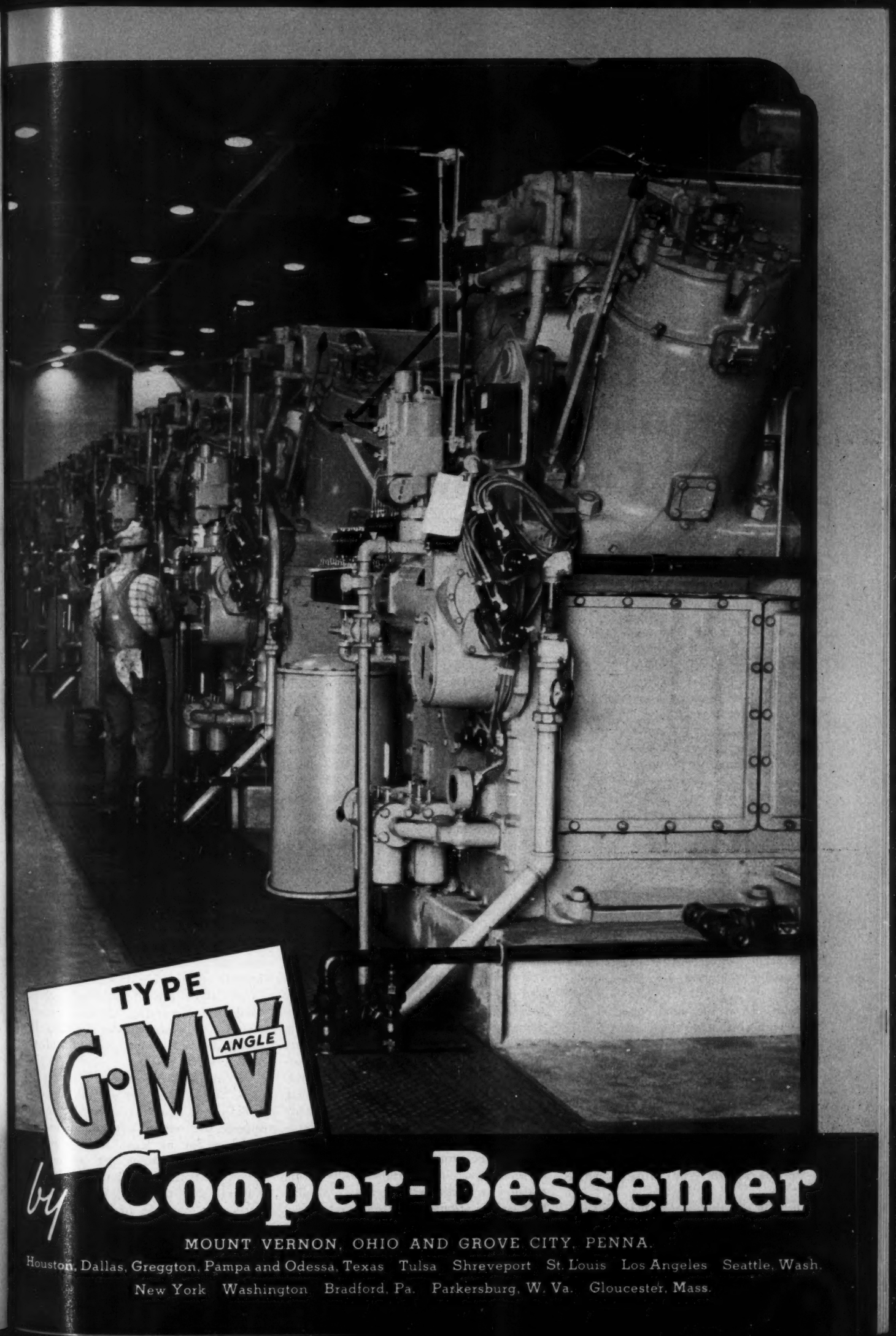
The approach to the problem has been to expand the educational part of the plant safety program into a 24-hour, round-the-clock safety activity, giving emphasis to the vital off-the-job phase of a worker's daily routine.

Thus the psychological effect is that there are not two safety programs, but only one which does not make a sharp distinction between off-the-job and on-the-job periods. It is a blend of the two which permits emphasis to be placed wherever it is most needed at the time.

Some months ago the National Safety Council created a special Off-the-Job Safety Committee which is conducting a nationwide campaign against accidents to workers while they are away from work — cooperating with individual plants directly and also through local safety councils.

The committee's first job was, of course, to collect and coordinate every scrap of available information and experience about how workers are accident-injured off the job. This has been done. It also was necessary to prepare a campaign for wartime industry—that is, a program designed for simplicty, one which would require industry to establish no new routines.

The resulting program consists of the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following: special posters on specific off-the-job subjects for plant bulletin boards, cartoons and feature articles for plant magazines and newspapers, leaflets for distribution or mailing directly to workers, a leaflet containing data and discussion suggestions for plant meetings of safety committees, two sound slide films for such meetings, a data sheet on plant parking and safety at loading points.

More than 2,000 plants are using all or most of these materials to curb their off-the-job accidents. A million leaflets already have been distributed to workers. More than 100,000 posters on the subject are appearing on bulletin boards. A thousand plant publications are carrying the cartoons and educational articles prepared especially for them.

And, mind you, until a few months ago management of these plants was not much more than dimly aware of the off-the-job problem and how it was affecting production.

Like everyone else, the National Safety Council is in this war up to its neck. It is under a special commission from President Roosevelt to continue a nationwide Save Manpower for Warpower campaign until peace again comes to the world. The biggest single job we have is to help industrial people and other employers with accident problems and thus increase both production and efficiency, as well as conserve manpower.

In important ways off-the-job accidents cause more trouble to industry than the on-the-job accidents. We believe we can help with this "after the whistle blows" portion of the safety problem. In fact, it is our war job to do so. We are anxious to cooperate in any way and to any degree that is helpful.

A letter to me at 20 North Wacker Drive, Chicago 6, Illinois, will get an answer to any query you may wish to direct to us.

Government Plant Proposed for Study Of Coal as Gasoline Source

A SERIES of public hearings in behalf of the proposal for building a demonstration plant for producing synthetic liquid fuels from coal and other materials was concluded August 11 at Sheridan, Wyoming. The open hearings were before a sub-committee of the United States Senate, headed by Senator Joseph C. O'Mahoney of Wyoming, author of the bill which would authorize construction of the plant.

Harold L. Ickes, Secretary of the Interior, was among the witnesses to appear in Washington. Previously he had summed up the situation as to oil reserves to Senator O'Mahoney as follows:

"The United States is losing ground as an outstanding producer of petroleum. Since 1938 the consumption of petroleum in the United States has exceeded the discovery of new reserves. I believe the time is at hand for more intensive research in the production of synthetic fuels, especially with regard to larger-scale demonstration plants, both for possible war use and in the post-war era."

Results from the small plant in the Pittsburgh station of the United States Bureau of Mines indicate that most of the coals mined in this country can be liquefied to produce gasoline, fuel oil, diesel oil and the other common petroleum products.

Information released by the United States Bureau of Mines gave the following concerning the liquefication of coal as well as results from working shale beds:

"In 1935, Congress granted funds to the Bureau of Mines to begin research in the production of liquid fuels from coal by hydrogenation and since then the bureau has continued its work in the small-scale unit at the Central Experiment Station at Pittsburgh. In processes employed by the bureau in its small plant, about 30 gallons of gasoline are produced from a ton of lignite and about 60 gallons from a ton of high-volatile bituminous coal. Coals from 14 American and Alaskan beds have been assayed and tested in the plant and the information compiled in the experiments is a valuable index to the potential yields of liquid fuels.

"Fuel oil, diesel oil and various by-products also are obtained. Additional studies are being undertaken by bureau technologists in breaking down the by-products to obtain chemicals for dyes, explosives, plastics, synthetic fibers, synthetic rubber, and other materials.

"The crude oil obtained from coal if generally similar to crude petroleum, according to Dr. R. R. Sayers, director of the Bureau of Mines, and it yields a relatively high percentage of gasoline and various oils. The process used by the bureau is known as the direct hydrogenation method. It involves mixing pulverized coal with oil to form a paste which is pumped together with compressed hydrogen into a converter. When heat and pressure are applied, the coal mixture is converted to crude oil, which is then "cracked" like petroleum to produce gasoline, light oil and other petroleum-like compounds.

"The gasoline obtained by this method is in almost every way similar to gasoline obtained from natural petroleum and can be treated to make high-grade aviation gasoline. England, Germany and Japan are all using this process to supplement their gasoline requirements for the war.

"In addition to the direct hydrogenation process employed by the bureau, there are other methods of producing liquid fuels from coal," Dr. Sayers pointed out. The bureau's initial work has been carried on in a small laboratory-size plant, and there are some refinements of the processes to be worked out before they can be adopted successfully on a commercial scale. The O'Mahoney bill, providing for government construction of larger-scale demonstration plants is designed to solve these problems.

From 1926 to 1929, the Bureau of Mines studied the extraction of oil from domestic oil shales but had to discontinue the project due to a shortage of funds. During this research, conducted near Rulison, Colorado, the bureau mined and retorted approximately 6000 tons of oil shale and produced 3600 barrels of shale oil. The largest reserves of oil shale are in Colorado, Nevada, Utah and Wyoming, although reserves also are found in Alaska, Indiana, Kentucky, Pennsylvania, Virginia and other states.

According to Bureau of Mines officials, the United States has about 3½ trillion tons of coal reserves—enough to supply the nation with solid fuel and gasoline for at least 1000 years. Reserves of oil shales are sufficient to produce about 92 billion barrels of oil. Natural gas reserves, the bureau reports, are capable of supplying "substantial quantities" of liquid fuels.

Development Of Oil-From-Coal Process Urged Before Senate Committee

THROUGH a series of hearings before a Senate sub-committee, representatives of government, the military and the petroleum industry in early August began to take stock of the prospects for liquid fuels for generations to come.

Peering into the future, they saw the possible exhaustion of petroleum reserves within a span of 15 years, but beyond that they visualized a natural gas supply from which oil products could be made for another 5 years, shale to carry us through the next 40 years and coal sufficient to supply both solid and liquid fuel for 10 centuries.

Needed only to tap the shale and coal reserves is the development of efficient methods for extraction of oil, and it was to consider means of prosecuting that development that government and industry representatives were called to testify at a two-day hearing before Senator O'Mahoney's war minerals subcommittee of the Senate public lands committee, on legislation providing for erection by the Bureau of Mines of demonstration plants for producing synthetic liquid fuels from coal and other materials.

While the project admittedly is one for post-war prosecution, it is O'Mahoney's belief that no time should be lost in getting it under way, and following the hearings in Washington the subcommittee moved on to Pittsburgh, Salt Lake City and Sheridan, Wyoming, to make further studies with a view to laying the legislation before Congress.

Expressing the belief that research on synthetic fuels should have been started before the war, Petroleum Administrator Ickes told the subcommittee that the program is designed to protect the country when the day arrives in which our oil resources become inadequate for our needs.

"It is no secret that our known petroleum reserves are limited, and that the time may not be far distant when they will be inadequate," he said. "For several years past we have been consuming petroleum nearly three times as fast as we have been able to discover new sources.

Government Leadership

"The idea that, somehow or other, sufficient new reserves of petroleum always will be discovered has its roots in wishful thinking. Natural petroleum does not accumulate like weeds, and we cannot produce more and more of it as we are able to grow trees through reforestation.

"We must insure our future security by launching a synthetic fuel program as embodied in the bill now under consideration, and we must do it without delay."

Because it is unlikely that private capital will venture into a new and untried industry, Ickes said, it is a field in which government leadership is necessary.

The administrator pointed out that the Bureau of Mines has already proven the possibility of converting most of the nation's bituminous coals and lignites into oil and has tested 14 American and Alaskan coals in a laboratory plant. Similar progress has been made with shales.

"This is not a promise to make synthetic fuel cheaper than natural petroleum products," he said. "It is a proposal to blaze the path now for private capital to do this job when we have no more natural domestic petroleum and it becomes a question of synthetic liquid fuel or the end of the gasoline age. Competition with the petroleum industry is not contemplated, the contrary rather, in this plea for synthetic fuel research. The future of the nation is at stake."

Production of gasoline from coal, lignite or oil shale, so far as now can be foreseen, will be more costly than from petroleum and no single company is in a position to risk money in its development unless the time of actual sale of the products at a profit is reasonably near, it was pointed out by Dr. R. R. Sayers, director of the Bureau of Mines.

Failure to develop substitutes for petroleum, Sayers warned, will leave the country as it was left with respect to rubber after the outbreak of the war, and it is believed we should not permit our military and essential services to be dependent upon foreign sources of fuel.

At this moment, he told the subcommittee, we are fighting an enemy—Germany—which has little natural petroleum other than what she has captured, but is able to keep thousands of tanks, trucks, motorized guns, planes and submarines in action with synthetic fuels.

Sayers explained that it may take years to work out a commercially successful process, pointing out that it took the Germans 13 years to put their first commercial-scale plant in operation to convert coal to oil. Less time will be required here, however, because of this background of development in past years.

Taking the position that if there is no oil there will be no oil business, Deputy Administrator Davies foresaw the actual development of the synthetic oil industry by the companies now engaged in the natural petroleum field. Already, he said, the industry has done considerable work along this line and has an important patent interest in its development.

The interest of the Army also was indicated by Brigadier General W. E. R. Covell, in charge of the fuels and lubricants division of the Quartermaster Corps, who testified that 50 percent of the overseas tonnage going to the fighting forces consists of oil and products and in the case of the North African occupation the proportion reached 65 percent.

Supporting his testimony with charts based on many years' research in hydrogenation as manager of the research and development department of Standard Oil Company of Louisiana, the Hydro Engineering & Chemical Company and Standard Oil Development Company, of which he is now executive vice president, R. P. Russell told the subcommittee that it takes about 1000 pounds of coal to make a barrel of gasoline by the hydrogenation process and 1300 pounds by the Fischer process, while with application of the latter to natural gas the weight of necessary raw materials shrinks to approximately 400 pounds; in petroleum hydrogenation plants, or in modern refineries employing catalytic cracking, the raw material requirements per barrel of gasoline is between 300 and 400 pounds.

Taking the 300,000-barrel capacity of the Big-Inch pipe line as a measure, Russell said that to build a plant producing that much gasoline daily from coal would require an investment of $2,225,000,000, while to produce the same amount from natural gas would involve a plant investment of only $600,000,000, while for production from natural crude oil it costs only $210,000,000.

The production cost of the gasoline would be about 16 cents a gallon for a large coal plant using the hydrogenation process and 19 cents by the Fischer process as between 5 and 6 cents in an oil refinery.

In the light of these considerations, he said, "it has been my own belief that if crude supplies should dwindle to a critical minimum, the next major sources of petroleum products would probably be natural gas, tar sands and oil shale." Our petroleum supplies, he figured, will carry us to 1955 or 1960; natural gas will tide us over the next 5 years and oil shale will carry us through to the year 2000.

Secondary Recovery Urged

Disagreeing with PAW officials as to the extent of our reserves, Gustav Egloff of the Universal Oil Products Company, urged adoption of a program for secondary recovery, and the manufacture of gasoline from natural gas, oil shale and oil sands before undertaking coal hydrogenation, although, he said, the government should develop methods of synthesis as insurance for the future.

Egloff asserted that present recovery methods leave 70 to 80 percent of the oil in the ground and that our use of natural gas is highly wasteful. He contended that a much greater proportion

of the underground oil should be recovered and testified that the processing of oil sands would be cheaper than hydrogenation of coal.

Our underground reserves of natural gas are sufficient for 56 years, Egloff said. Last year, consumption amounted to 31 billion cubic feet which, if converted into gasoline even by present methods, would have yielded 40 billion gallons, or 14 billion gallons more than was consumed.

Egloff warned that hydrogenation would require much manpower, testifying that it would require 8,000,000 men to produce a year's supply of gasoline from coal.

PAW Assistant Deputy Administrator Bruce K. Brown told the subcommittee gasoline could be produced from natural gas at prices competing with present crude-oil gasoline, but would require reasearch and development to improve methods of hydrogenation.

"With improvements resulting from research, development and operating experience," he said, "this process may be competitive with crude oil at $2 a barrel or even less."

The cost of gasoline from coal was estimated by Brown at from 10 to 25 cents a gallon.

Brown estimated the life of our natural gas reserves at only 30 years on the basis of an annual consumption of three trillion cubic feet, but calculated the potential production of oil from shale at 92 billion barrels. Shale oil will be an important item in our future liquid fuel economy, he said, but much work remains to be done to produce modern motor and aviation fuels from shale.

Other hydrocarbon resources mentioned by Brown were the oil sands of Utah and other locations which have not been thoroughly explored but probably could produce several years of fuel supply by the application of proper technology. The Canadian deposits of oil sands have been estimated at from 125 to 250 billion barrels, he said.

The final part of the hearing was devoted to a discussion of German synthetic oil production with C. Stribling Snodgrass, associate director of the PAW foreign division, testifying that Germany has completed an "ambitious" four-year plan for synthetic plant construction.

"She has, in fact, not only reached the output called for in that plan, but by the beginning of 1944 will have substantially exceeded it," Snodgrass said. "Barring military damage or destruction, the capacity of these synthetic plants (as supplemented by other sources of oil from coal) will approach 50 percent of the total European-Axis controlled supplies of liquid fuel."

John O'Mahoney of the Alien Property Custodian's office reported to the subcommittee that the American Lurgi subsidiary had been taken over last November. He said he understood the Lurgi process is responsible for most of the gasoline being produced in Germany.

The American company, however, has had no experience in the production of gasoline but is now conducting tests, it was testified by Dr. Frank Mueller, head of the company. The company produces creosote oil and smokeless fuel out of Utah coal, and has a process for carbonizing coal into tar, from which gasoline can be made by a further process.

NPA Annual Meeting to Be Held in New York

The forty-first annual meeting of the National Petroleum Association will be held in New York, September 21 and 22. Sessions will be in the Waldorf-Astoria Hotel.

The program will deal with questions that pertain to the war as well as to proposals of the post-war period.

Coleman Heads PAW Program Division

A program division of the Petroleum Administration for War has been set up as a means of providing adequate petroleum supplies for the war effort. Stewart P. Coleman, who has been chairman of the subcommittee of the committee on economics of the Petroleum Industry War Council, has been named director of the new division.

Ralph K. Davies, deputy petroleum administrator, made the following explanation of the new division:

"As the United Nations shift to the offensive on a global scale, petroleum becomes the most important single commodity required by our armed forces, its tonnage approximating the total tonnage of all other war supplies combined.

"Both the military operations and the accompanying petroleum supply problem are international in scope and it becomes increasingly necessary to develop a tightly knit and thoroughly coordinated petroleum supply program to meet the military and essential civilian requirements of the United Nations.

"The new Division, after review and consultation with the Economics Committees of both the Petroleum Industry War Council (representing domestic oil operators) and the Foreign Operations Committee (representing foreign oil operators), will report on suggested program alternatives for execution by PAW.

"The Program Division will absorb part of the work and act as a clearing house for the remainder of the activities hitherto carried on by the programming sections of the PAW functional divisions. Formerly these activities were coordinated through inter-divisional liaison."

Coleman was director of the department of economics, Standard Oil Company of New Jersey, when he went to PWIC in 1942. He was with Humble Oil & Refining Company prior to 1933, when he went to Standard Oil Company of New Jersey as director of manufacturing coordination. He entered the petroleum industry following graduation from Rice Institute in 1920 and was in charge of refinery research and technical work.

LISTED

Even the fact that lists of butadiene plants published by the government ignore the unit of Shell Oil Company at Houston is little consolation to the staff of *Petroleum Refiner*, which also has ignored the plant.

This unit is not a part of the war plant program, for the reason that it has been making butadiene for four years, a start well ahead of the urgency that came with the loss of rubber from the Far East.

Its output, 5000 tons per year, was a vital part of the synthetic rubber program while the larger butadiene plants were building. The rubber companies drew upon its output for their supplies of butadiene for experimental purposes.

In all lists of butadiene from petroleum units, Shell Oil Company, Deer Park plant, Houston, has a place.

Reeser Retires as Head Of Barnsdall Oil Company

E. B. Reeser, president of Barnsdall Oil Company since 1925, retired August 1. James A. Dunn, vice president and secretary, has been elected president. W. C. Whaley, vice president, has been named manager of the California division to succeed Dunn, whose headquarters will be in Tulsa. D. R. Snow, vice president, has been named general manager of the Mid-Continent division.

Reeser has been connected with the petroleum industry for 50 years, 40 of which were with the Barnsdall interests. He served three terms as president of the American Petroleum Institute.

High Pressure Well Study for Katy Field

Under the sponsorship of the Natural Gasoline Association of America, a study of the problems of distillate well production will get under way in the Katy high-pressure field near Houston August 9. Dr. G. G. Brown and Dr. D. L. Katz of the University of Michigan as well as some of their associates have been engaged on a full-time basis for conducting the study, whose principal objective will be the finding of a simple and effective means of sampling a two-phase gas stream.

Outline of the test as given out through the association was:

"Experiments are to be made with various types of equipment through a pressure range of from 1000 to 5000 pounds per square inch, on streams containing up to about 10 percent liquid phase by volume. Other experiments are to be made with new methods for determining the specifice gravity and liquid content of such gases. Elaborate full-scale equipment has been set up at well No. 9 of the Katy unit under the supervision of W. A. Van Hook and Carl J. Mantzell, Stanolind Oil & Gas Company."

The plan of testing and the layout of equipment were determined by C. R. Williams, Chicago Corporation, Corpus Christi, vice president of the high-pressure division of the association; R. J. Sullivan, Humble Oil & Refining Company; M. R. Church, Shell Oil Company; W. L. Bowser, The Atlantic Refining Company; J. R. Butler, Cotton Valley Operators Committee, and D. A. Sillers, Lone Star Gas Company.

Other companies participating in the project are J. S. Ambercrombie Company, Arkansas Fuel Oil Company, The Carter Oil Company, Cities Service Oil Company, Continental Oil Company, Gulf Plains Corporation, Houston Oil Company of Texas, La Gloria Corporation, Lockhart Oil Company of Texas, Magnolia Petroleum Company, Ohio Oil Company, Phillips Petroleum Company,

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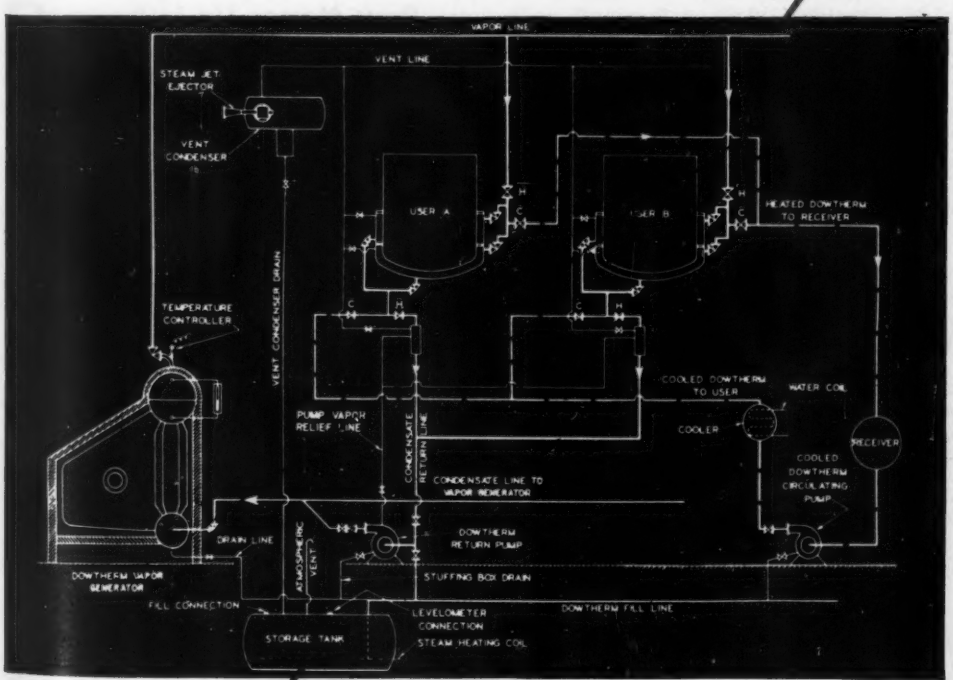

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Scheumann Transferred To Lake Charles Plant

W. W. Scheumann, general superintendent of Cities Service Oil Company (Delaware), has transferred to Cities Service Refining Corporation, and will be in charge of chemistry at the new refining plant now being completed at Lake Charles, Louisiana. This plant will make 100-octane gasoline and butadiene.

His transfer brought F. M. Simpson into the position of general superintendent of the two refining plants of the Delaware company, Ponca City, Oklahoma and East Chicago, Indiana.

Scheumann has been in the Cities Service organization since 1924, when he went to the East Braintree plant as a chemist. Two years later he became chief chemist at this plant. In 1931 he joined a subsidiary, Empire Oil & Refiining Company, as a chemist at the Okmulgee plant. In 1937 he became chief chemist of the refining division, a place he held until March 1, 1942, when he became general superintendent of refining of Cities Service Oil Company (Delaware.)

Scheumann is a graduate of Purdue University in chemical engineering.

Simpson is a Texan who went with Cities Service Refining Company following his graduation from Texas Agricultural and Mechanical College. After completing assignments in refining, natural gasoline and motor transportation as a junior engineer, he came into the refining division. He worked for two years in the Ponca City plant before going into headquarters, then in Tulsa.

Heath Is President of California Association

R. W. Heath, manager of the gas department of Signal Oil & Gas Company, Los Angeles, was elected president of the California Natural Gasoline Association at the annual meeting directors in July.

Vice president for the 1943-44 period is C. D. Card, Union Oil Company.

Five additional members were added to the board of directors: I. B. Funk, Cowan Oil & Refining Company; John C. Herron, Shell Oil Company; W. L. Rifenberick, Industrial Engineers, Inc.; J. H. Sargent, Kettleman Hills North Dome Association, and J. B. Taylor, Signal Oil & Gas Company.

Shaw Joins Anchor Petroleum Company

Tom C. Shaw has been appointed head of the engineering and operations departments for Anchor Petroleum Company, Tulsa, Oklahoma, producers and marketers of butane and propane.

Shaw, a native Texan, has been a resident of Tulsa for two years, and has been associated with Stanolind Oil and Gas Company. Previously, he was in charge of manufacturing for the Coronado Corporation, Corpus Christi, Texas.

Research Program for Pennsylvania Oils

Part of a research program authorized by the Pennsylvania Grade Crude Oil Association will be directed toward expanding the uses of oils from that area. The complete research program was authorized by the association at its meeting in June. Increasing the output of crude oil will be the other objective. A research director will be employed for the complete program.

Concerning the refining phase information released through the association was to this effect:

"There are two definite objectives in the proposed studies; first, the maintenance of Pennsylvania's leadership in quality lubricants; and second, the development of new and varied products from Pennsylvania-grade crude. This latter field is expanding rapidly under the stimulus of the war program and many Pennsylvania oil men believe that the industry's best future lies in that direction."

Moore Is Superintendent Of Bakersfield Refinery

Merle M. Moore has been appointed superintendent of the Bakersfield plant of Standard Oil Company of California. His promotion was from assistant superintendent of the lubricating-oil department of the Richmond plant.

He succeeds C. A. Swigart, who will devote all his time to superintendent of the central pipe-line division, duties he previously held along with superintendent of the Bakersfield plant.

Moore has been with the company since 1913, when he came to the El Segundo plant following graduation from the University of Kansas. In 1931 he transferred to the Richmond plant.

Dodge Advanced by The Texas Company

F. P. Dodge, who has been manager of the Port Arthur plant of The Texas Company, has been promoted to assistant to the general manager of the refining department. He has been assigned to some special duties and will continue to make headquarters in Port Arthur.

F. L. Wallace, superintendent of the Port Arthur works since 1939, has been named manager. The post of superintendent will be filled by D. P. Bailey, who is returning to The Texas Company after a period of duty with the Petroleum Administration for War.

Dodge has seen service in many of the refining plants of The Texas Company. After graduation from Pennsylvania State College he went to Port Neches as yard foreman in 1906. A year later he took charge of construction of the plant at West Dallas, where he remained and became superintendent in 1910. In 1911 he had charge of construction of the Lockport plant. He came to the Port Arthur works in 1914 as assistant superintendent, became general superintendent in 1918 and manager in 1939.

Wallace is a graduate of Purdue, who came to The Texas Company after two years of military service in the first world war. His work in 1939 was in the power department at Port Arthur. In 1922 he became foreman of this department. In 1930 he became second assistant general superintendent, assistant superintendent in 1934 and general superintendent in 1939.

Bailey is a graduate of the University of Texas, who came to The Texas Company as a chemical engineer at Port Arthur in 1927. Two years later he was assistant supervisor of vertical stills. In 1930 he went to West Tulsa as assistant superintendent, taking a similar position at Lockport in 1932 and becoming acting superintendent there two years later.

He joined the export sales department in June, 1934, and was assigned to the plant at Ambes, France. He returned to the United States in 1941 and was assigned to the managerial section of the refining department in New York. Since January, 1942, he has been on leave of absence with PWA.

Holsten Again Heads Gulf Coast Refiners

Frank E. Holsten, Chalmette Refining Company, New Orleans, was reelected president of the Gulf Coast Refiners Association at the annual meeting at Houston July 27. He will continue to represent the independent refining industry of the area on the Petroleum Industry War Council and will be a member of the refining committee of District 3, PAW.

Other officials are John A. Bartlett, American Mineral Spirits Company, Corpus Christi, and George O. Irvine, American Republics Corporation, Houston, vice presidents; L. F. Rothermel, Maritime Oil Company, Houston, treasurer. George H. Reid will continue to serve as executive secretary.

Pew Moves Up in Natural Gasoline Division of PAW

James E. Pew, who has been chief of the natural gasoline section of the Petroleum Administration for War, has been named assistant director of the Division of Natural Gas and Natural Gasoline. He succeeds Paul M. Raigorodsky, who resigned July 1. Charles E. Webber, who has been assistant to Pew, has been appointed chief of the natural gasoline section.

Pew has been engaged in natural-gasoline activities for 20 years. After graduation from Cornell University and Massachusetts Institute of Technology, he joined United Natural Gas Company, Bradford, Pennsylvania, where he was engaged in the construction and operation of a charcoal-adsorption-process natural-gasoline plant. During 1924 to 1926, he was with Hope Construction and Refining Company, of Pittsburgh, working in the laboratory of Mellon Institute on research and development studies in connection with natural gasoline and liquefied petroleum gases.

For 16 years, from 1926 to 1942, he was associated with the Virginian Gasoline and Oil Company, of Charleston, West Virginia. He advanced to superintendent in charge of operation of the company's natural-gasoline plants and later was made manager of Viking Distributing Company, a subsidiary organization engaged in marketing motor fuel.

Pew was called to PAW in January, 1942, as a member of the Production Division. When the Natural Gas and Natural Gasoline Division was formed in June, 1942, he was made chief of the Natural Gasoline Section.

Webber was born in Stillwater, Okla-

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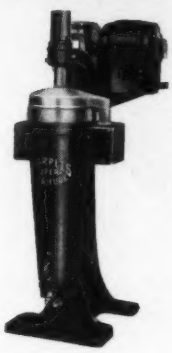

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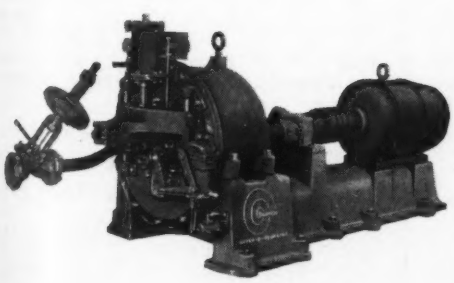

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homa, and was educated in Pittsburgh, Pennsylvania, and Baton Rouge, Louisiana. He received an M.A. in chemical engineering from Louisiana State University in 1934. He was employed by Humble Oil & Refining Company, from 1934 until June, 1942, when he joined PAW as assistant to Pew in the Natural Gasoline Section.

Refining Director to Issue PAW Directives

Operating directives to petroleum refiners will be issued by E. D. Dumming, director of refining, Office of the Petroleum Administration for War. Authority to act in this capacity was given by Ralph K. Davies, deputy administrator.

Scope of the authority is given in this part of the delegation of authority:

"You may issue to the refiners in the various districts, by telegrams or otherwise, necessary operating directives relating to the extent and character of refinery operations, including without limitation directives as to the permissive amounts of crude to be run and products to be made therefrom under Plan 15 and such other Plans, Orders, Recommendations, Directives, or policy determinations as may from time to time be issued by the Petroleum Administration for War."

Cooperative Buys Globe Plant at McPherson

National Cooperative Refinery Association has purchased the plant of Globe Oil & Refining Company at McPherson, Kansas. The association was incorporated in Kansas early in July with five members, including Central Cooperative Wholesale, Superior, Wisconsin; Midland Cooperative Wholesale, Minneapolis; Farmers Union Central Exchange, St. Paul; Farmers Union Exchange, Omaha, and consumers Cooperative Association, North Kansas City.

Sale of this plant and the products line to Council Bluffs, Iowa, leaves Globe Oil & Refining Company with its 27,000-barrel newer plant at Lemont, Illinois.

The McPherson plant has daily capacity of 15,000 barrels. A. E. Landsittle, who has been sales manager for Globe Oil & Refining Company, has been named general manager at McPherson.

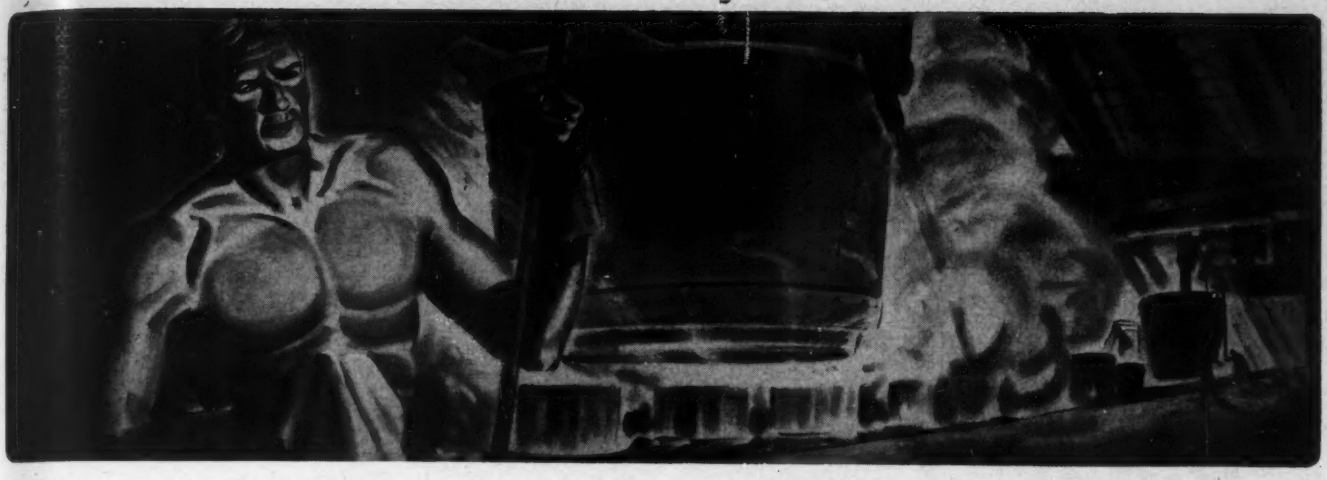
Gas Institute Starts Technology Review

The Institute of Gas Technology has issued the first number of "Gas Technology Review," an abstract journal, which will be issued quarterly for the present. Its purpose is to review the current literature and patents, both domestic and foreign, in all aspects of gas technology.

The publication plan and subscription rates were approved by the board of trustees in May. During the first year publication will be quarterly and copies will be free to members. Subscription rates to non-members will be $6 per year. Monthly publication is contemplated when conditions permit.

Information given publication along with the new first issue gave these details:

"The new publication is solely an ab-



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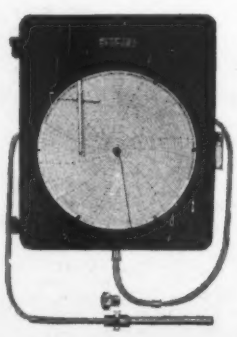

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stract journal and is not copyrighted. Its abstracts may be quoted if the source is acknowledged. To some extent the review is self-indexing by reason of its classified arrangement. Abstracts are printed in a form which permits mounting on index cards, and the style is designed to facilitate rapid scanning for interesting topics. The first issue has been sent to gas companies and appliance manufacturers throughout the United States, and to many technical libraries. Other interested persons may obtain copies from the technical librarian, Institute of Gas Technology, 3300 Federal Street, Chicago 16, Illinois.

PIWC Names Committee To Study Rationing

Because of the prospect for revision of gasoline-rationing regulations the Petroleum Industry War Council has named a special committee which will made a detailed study of the subject. Along with naming the committee William R. Boyd, Jr., chairman, made it clear that the organization does not function as a rationing agency but must concern itself with providing both military and civilian gasoline requirements.

John A. Brown, Socony-Vacuum Oil Company, was named chairman of the special committee. Other members are C. S. Beesemyer, Gilmore Oil Company, Los Angeles; J. W. Carnes, Sinclair Refining Company, New York; R. H. Colley, The Atlantic Refining Company, Philadelphia; H. D. Collier, Standard Oil Company of California, San Francisco; R. E. Decker, National Oil Marketers Association, Detroit; W. Alton Jones, Cities Service Oil Company, New York; J. Sayles Leach, The Texas Company, Houston; J. A. Lentz, Continental Oil Company, Denver; B. L. Majewski, Deep Rock Oil Corporation, Chicago; Charles F. Roeser, Roeser & Pendleton, Fort Worth, and E. G. Seubert, Standard Oil Company (Indiana), Chicago.

Neither the oil industry nor the Petroleum Administration for War has the authority to decide what the gasoline rationing system should be, Boyd explained. Our joint responsibility has been and still is to supply the gasoline to be rationed and that duty makes it only right that the oil industry should suggest ways to make the rationing system as effective as possible.

Hydrocarbon Manual Is Now Available

The fourth edition of "Physical Constants of the Principal Hydrocarbons," is now available through M. P. Doss, The Texas Company, 135 East Forty-second Street, New York. The price is $3.75.

This revision was made at the request of the technical advisory committee of the Petroleum Industry War Council, so as to give the petroleum industry the advantage of data on its new products.

The third edition was issued in March, 1942, and contained 215 pages and listed the properties of nearly 2,000 hydrocarbons. More than 100 pages of the third edition have been revised for the fourth edition in order to include new or corrected data, particularly on the hydrocarbons related to the manufacture of aviation gasoline, synthetic rubber, synthetic resins, toluene and other products.

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DIGEST OF UNITED STATES PATENTS

On Alkylation of Hydrocarbons II

Compiled by Heinz Heinemann

U.S.P. 2,283,603. Treatment of Hydrocarbons. A. V. Grosse and C. B. Linn to Universal Oil Products Company. C.A. 36,4693.

Butane is treated with acetylene in the presence of $AlCl_3$ and hydrogen halide at a temperature above 0°C. but not appreciably above 50° (suitably about 25-30°) and under sufficient superatmospheric pressure to maintain a substantial portion in the liquid phase.

U.S.P. 2,281,248. Process of Alkylating Hydrocarbons. D. H. Putney to Stratford Development Corporation.

Iso-paraffins are alkylated with olefins in the presence of a condensation catalyst in an alkylation stage. The catalyst is recycled for reuse. Olefin hydrocarbons are selectively absorbed in the catalyst prior to alkylation and the residence period of contact of the catalyst and olefins is limited in minutes to less than 1/10 of the volumetric catalyst/olefin hydrocarbon ratio. Temperatures during the residence time of the olefins in the catalyst should be below 50° F.

U.S.P. 2,282,505. Catalytic Alkylation Process. H. G. Vesterdal to Standard Oil Development Company.

Chlorosulfonic acid diluted with liquid sulfur dioxide prior to being mixed with the hydrocarbon reactants is employed as an alkylation catalyst mixture for effecting the condensation of iso-paraffins with mono-olefins to produce liquid, saturated, branched-chain hydrocarbons. Alkylation temperatures from 0°F to 100°F and preferably from 10 to 40°F can be used without disintegrating the chlorosulfonic acid. At least a 2:1 molar ratio of iso-paraffin to mono-olefin is desirable. The chlorosulfonic acid can be of commercial grade that is slightly less than 100 percent. It may be reactivated by heating with elemental sulfur or carbon. The amount of SO_3 used may vary between 10 and 50 (wt) percent of the total catalyst consumption.

U.S.P. 2,283,603. Manufacture of Motor Fuel. A. R. Goldsby and F. H. Bruner to The Texas Company.

Low-boiling hydrocarbons, containing i-butane, n-butane and olefins are continuously introduced to a reaction zone containing an alkylation catalyst and are alkylated in the liquid phase. The product is continuously removed and separated. Iso-butane is recycled and fresh catalyst is constantly added to the reaction zone.

U.S.P. 2,284,554. Condensation Catalysts of Increased Activity and Process of Producing Same. F. J. Beyerstedt to Standard Oil Development Company.

A process for increasing the activity of a boron trifluoride-water condensation catalyst containing organic impurities but whose effective amount of boron trifluoride is at least 55 weight percent is described, which comprises subjecting at least a partially deactivated boron trifluoride-water catalyst of said type to heat only sufficient to volatilize off enough BF_3 to effect a substantial separation of the residue into a catalyst layer and a hydrocarbon layer removing the hydrocarbon layer and introducing boron trifluoride into the catalyst layer in such amounts as to produce a catalyst substantially equivalent in chemical composition to that originally employed in organic condensation reactions.

U.S.P. 2,286,183. Alkylation of Iso-Paraffinic Hydrocarbons. W. E. Bradley and K. J. Korpi to Union Oil Company of California.

Certain oxidation inhibiting or mitigating agents are added to the alkylation catalyst to prevent polymerization of the olefins. Approximately 5 percent of diamyl-ether is used as such an agent in connection with a sulfuric-acid catalyst. Temperatures of approximately 75°F. and pressure of about 90 pounds are employed and a reaction time of 8 hours is used.

U.S.P. 2,286,504. Process of the Alkylation of Iso-Paraffins. F. D. Parker to Union Oil Company of California. C.A. 36,7272.

An arrangement of apparatus is described and a process for the production of branched-chain saturated hydrocarbons boiling within the gasoline range, involving the reaction of iso-paraffinic hydrocarbons such as those having less than 7-C atoms per molecule with normally gaseous olefinic hydrocarbons, in the presence of an alkylation catalyst such as sulfuric acid and including the steps of bringing the gaseous olefins into contact with a hydrocarbon liquid-absorbing medium prior to contact with the i-paraffins and the alkylation catalyst, thereby producing a liquid mixture containing the absorbed olefins, commingling this mixture with liquefied i-paraffin to be alkylated and with the alkylation catalyst, thereby forming alkylation products comprising the branched-chain saturated hydrocarbons and employing these alkylation products as the liquid-absorbing medium.

U.S.P. 2,286,543. Process of Alkylating Hydrocarbons. H. Heinemann to Danciger Oil & Refineries, Inc.

Iso-paraffins may be alkylated with olefins by causing the components to react at an elevated temperature and under superatmospheric pressure in the presence of a catalyst which contains as active ingredients a metal halide selected from the group consisting of the halides of zinc, aluminum, iron and tin and as an activator or promoter, an oxygen containing compound of antimony, selected from the group consisting of antimony compounds obtained by hydrolytic decomposition in aqueous solution of a water-soluble compound of antimony, oxides and oxide hydrates of antimony, oxy-acids of antimony and antimony compounds obtained by acidifying an aqueous solution of an antimonic salt. The metal halide may be present wholly or partly dissolved in water. Solid carriers may be used.

U.S.P. 2,290,211. Alkylation of Aromatic Hydrocarbons. R. E. Schaad to Universal Oil Products Company.

An aromatic hydrocarbon and an olefinic hydrocarbon are contacted under alkylation conditions in the presence of a catalyst comprising as its active ingredient an acid phosphate of an alkaline earth metal. Carriers are used. Temperatures of from 250 to 400°C and pressures up to 100 at. are employed.

U.S.P. 2,293,705. Treatment of Paraffin Hydrocarbons. H. S. Bloch to Universal Oil Products Company.

A charge stock of n-butane is purified by treatment with concentrated sulfuric acid. The treated n-butane is then mixed with hydrogen and hydrogen chloride and isomerized in the presence of a metal chloride catalyst. The i-butane formed, commingled with recycle i-butane from the alkylation step, is mixed with an olefin-containing stock and subjected to the action of used sulfuric acid, obtained for the n-butane purifying step, under alkylation conditions.

U.S.P. 2,295,608. Alkylation Catalyst. R. F. Ruthruff. C.A. 37,1130.

Concentrated sulfuric acid containing a mercury compound and a selenium compound is used as a catalyst, as in the alkylation of i-butane or benzene by reaction with an olefin such as i-butane.

U.S.P. 2,298,383. Treatment of Hydrocarbons. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

A major portion of i-butane and a minor portion of acetylene are alkylated in the presence of a hydrogen halide and a composite catalyst consisting of a substantially inert carrier and aluminum chloride prepared in the same manner as described in U.S.P. 2,318,781 (see below). The alkylation is carried out at a temperature of -25 to 200°C and a pressure ranging from atmospheric to 1000 pounds. Three mols of i-paraffin should be used per mol of olefin and hydrogen halide is added to the extent of 0.5 to 15 percent by weight of the total hydrocarbon mixture.

U.S.P. 2,301,615. Treatment of Hydrocarbons. J. A. Chenicek and K. M. Brown to Universal Oil Products Company.

A combination isomerization and alkylation process is described. See Digest of United States Patents on Isomerization.

U.S.P. 2,303,663. Motor Fuel Manufacture. R. V. Shankland to Standard Oil Company (Indiana).

A method is employed for the treatment of a mixture containing considerable proportions of n-butane and i-butane which involves fractionating the mixture in a fractionating zone to form a fraction rich in butane and a fraction rich in i-butane, dehydrogenat-

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ing a portion of the fraction rich in butane to form butylenes and hydrogen, introducing the butylenes and the fraction rich in i-butane into an alkylation zone containing a catalyst and maintained under conditions suitable for the reaction of butylenes and i-butane to form branched-chain octanes, removing the products from the alkylation zone, separating a normally liquid fraction containing the octanes and a normally gaseous fraction from the products, isomerizing n-butane and reintroducing this to the alkylation zone.

U.S.P. 2,303,735. Manufacture of High-Anti-Knock Hydrocarbons. A. R. Goldsby to The Texas Company.

A hydrocarbon mixture containing a large proportion of straight-chain hydrocarbons boiling over a substantial range of temperature such as derived from the catalytic dehydrogenation of naptha or obtained by the catalytic conversion of CO and H, is fractionated into fractions of relatively narrow boiling range. Each fraction is subjected to alkylation with an i-paraffinic hydrocarbon, preferably i-butane and the alkylated fractions are subjected to further treatment such as isomerization.

U.S.P. 2,304,290. Alkylation Process. A. J. van Peski to Shell Development Company.

Saturated aliphatic hydrocarbons may be advantageously alkylated in the presence of Friedel-Crafts catalysts by reaction with olefinic polymers instead of the olefins themselves. Most preferably, highly viscous polymers of aliphatic character are used. Such polymers may be prepared by treatment of olefins, diolefins, etc., with aluminum halides, boron trifluoride or the like. Preferably low-temperature polymerization under conditions at which high molecular polymers, boiling above the gasoline boiling range are formed, is used. The most advantageous alkylation conditions depend on the nature of paraffins and polymers. Temperatures between 0° and 100°C are preferred. At least 1.1 mols and better 2 or more mols of reacting paraffins are used per mol of starting olefin in the polymer. Catalyst activators are employed.

U.S.P. 2,305,026. Motor Fuel and Process for Making Same. J. C. Munday to Standard Oil Development Company.

Iso-paraffins such as i-butane and an olefin such as butylene are subjected to the action of an alkylation catalyst such as sulfuric acid of 90 to 100 percent. The reaction product is separated into a heavy and into a light fraction, the latter including only those hydrocarbons boiling within the gasoline boiling range. The heavy fraction is subjected to a further reaction with at least one i-paraffin or an aromatic hydrocarbon under alkylation conditions and in the presence of an alkylation catalyst. From the reaction product a hydrocarbon fraction containing alkylated hydrocarbons boiling within the gasoline boiling range is recovered and combined with the previously obtained light fraction.

U.S.P. 2,307,773. Treatment of Hydrocarbons. Gustav Egloff to Universal Oil Products Company.

Paraffin hydrocarbons are reacted with fluorine at low temperatures and form alkyl fluorides and hydrogen fluoride. Normal-butane, for instance, is treated at -10°C by gradually adding a mixture of 5 percent fluorine and 95 percent nitrogen to produce approximately an 80 percent yield of mono-fluor butane. The mixture of the alkyl fluoride and hydrogen fluoride is then in a second step contacted with an i-paraffin, for instance with i-butane, at 0°C. Alkylation to a product consisting predominantly of octanes of isomeric character occurs.

U.S.P. 2,307,799. Alkylation of Paraffinic Hydrocarbons. C. B. Linn to Universal Oil Products Company.

Alkyl fluorides are formed by the addition of HF to mono-olefinic hydrocarbons at a temperature within the approximate range of -60 to 100°C and more preferably at a temperature of the order of -30 to 0°C and under a pressure sufficient to maintain in liquid phase a substantial proportion of the reaction mixture. Polymerization tends to occur at higher temperatures. A mixture of liquid HF and an i-paraffin is agitated and a mixture of an alkyl fluoride and an i-paraffin is introduced gradually, suitably below the surface of the HF-iso-paraffin mixture. The alkylation may be carried out at -10 to 75°C and preferably at a temperature of about 20°C.

U.S.P. 2,311,144. Apparatus for Hydrocarbon Alkylation. H. P. Wickham and M. M. Perkins to The M. W. Kellogg Company.

An apparatus for effecting hydrocarbon alkylation in the presence of a sulfuric-acid catalyst is described which comprises a closed vessel partitioned into at least two liquid compartments, an inlet connection terminating inside and near the bottom of one of said compartments in a plurality of constricted openings adapted to emulsify liquid mixtures introduced therethrough, an emulsion outlet connection accessible from said compartment only at a higher level than that at which said inlet connection terminates, a hydrocarbon outlet connection accessible from said compartment only at an appreciably higher level than that at which said emulsion outlet connection is accessible, a conduit leading from said hydrocarbon outlet connection into a second compartment of said vessel, a connection for withdrawing hydrocarbons from said second compartment which is accessible only at a level appreciably above the bottom thereof, and a connection for withdrawing catalyst liquid from the bottom of said second compartment.

U.S.P. 2,312,539. Manufacture of Gasoline. F. E. Frey to Phillips Petroleum Company.

A hydrocarbon mixture containing ethylene and heavier olefin hydrocarbons and also propane and heavier paraffin hydrocarbons is subjected in a first alkylation step to a reaction temperature and pressure in the presence of an alkylation catalyst for a period sufficient to effect a union of the heavier olefins with paraffins to produce an optimum yield of paraffin hydrocarbons in the motor fuel boiling range. Aside from motor fuel, a hydrocarbon mixture containing ethylene and light paraffins having at least 3 C-atoms per molecule is removed from the effluent and is subjected in a second alkylation step to alkylation conditions including a reaction temperature of 750 to 1100°F. under a pressure in excess of 500 pounds in the absence of a catalyst for sufficient time to produce a union of ethylene with paraffin to give an optimum yield of paraffins boiling in the motor-fuel range. A fraction containing normally liquid hydrocarbons of not more than 7 C-atoms per molecule is also separated from the effluent and returned to the second alkylation step.

U.S.P. 2,313,103. Alkylation of Paraffin Hydrocarbons. C. L. Thomas to Universal Oil Products Company.

Efforts to alkylate n-paraffinic hydrocarbons with olefins in the presence of catalysts have thus far failed. Iso-butane however, may be made to interact with olefins to produce saturated products, and with butenes and in particular i-butenes to form iso-octanes. An excess of i-paraffin is desirable to minimize polymerization. Fluorsulfonic acid, prepared by treating fluorospar with fuming sulfuric acid, is used as a catalyst. A mixture of fluorosulfonic acid and and i-paraffin is agitated and a mixture of an olefin and an i-paraffin is gradually introduced below the surface of the acid-paraffin mixture, while the reaction mixture is under pressure sufficient to keep a substantial proportion of the reactants in liquid phase. A temperature range of 0 to 100°C and pressure range of 2 to 20 atmospheres has been found suitable.

U.S.P. 2,313,660. Manufacture of High Octane Gasoline. C. W. Montgomery to Gulf Research & Development Company.

Iso-paraffin is alkylated with an olefin in the presence of an alkylation catalyst. The reaction product is washed with dilute aqueous alkali to remove acidic constituents. Higher-boiling i-paraffins are separated from hydrocarbons boiling in the gasoline range by fractionation of the washed reaction product. The higher-boiling iso-paraffins are dehydrogenated to i-olefins which are in turn alkylated with further quantities of lower-boiling i-paraffins in the presence of an alkylation catalyst.

U.S.P. 2,314,333. Chemical Process. A. W. Francis to Socony Vacuum Oil Company.

Olefins are first reacted with sulfuric acid to form alkyl esters thereof and the alkyl esters are then reacted with paraffins in the presence of concentrated sulfuric acid at a relatively low temperature adjusted with respect to the acid concentration, so that a high yield of high-octane motor fuel is obtained. The alkyl esters must be added slowly to the paraffins to avoid poor yields. This process almost eliminates polymerization. Less concentrated acid can be used for the catalyst. The concentration varies, other factors being equal, with the particular olefins being used. When i-paraffins are alkylated at about 30°C with free olefin, using propylene as the olefin, an acid concentration of 100 to 101 percent is recommended. When combining propylene indirectly with i-paraffin at 30°C by means of di iso propyl sulfate, an acid concentration of 97 percent is satisfactory. The low temperatures are undesirable because of poor yields due to freezing of the acid. Too high temperatures favor side reactions. A temperature of 50 to 60°C is considered to be optimum.

U.S.P. 2,314,435. Treatment of Hydrocarbons. S. S. Allender to Universal Oil Products Company.

A n-butane-i-butane gas mixture is fractionated. The n-butane is isomer-

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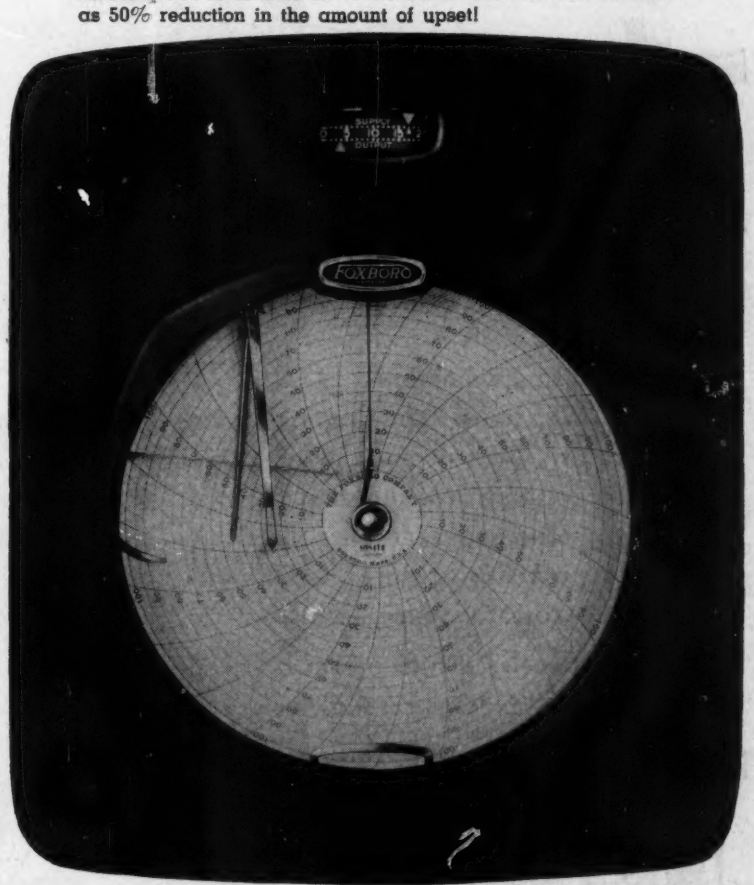

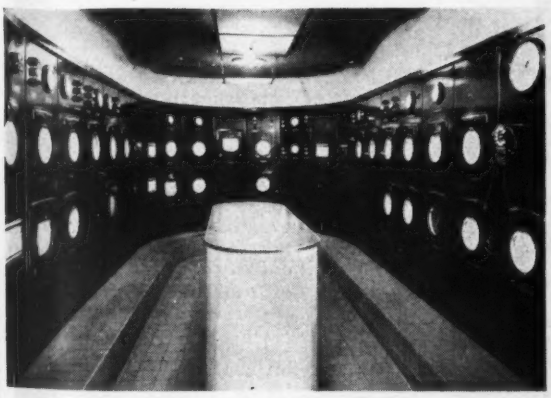

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ized, fractionated and the i-butane formed united with the original i-butane fraction. The combined n-butane fractions are dehydrogenated and the n-butenes formed are alkylated with the total i-butane fraction.

U.S.P. 2,315,078. Conversion of Hydrocarbons. H. Pines and V. N. Ipatieff to Universal Oil Products Company.

A process for producing substantial yields of alkyl cyclo hexane hydrocarbons from alkyl cyclo pentane hydrocarbons is described which comprises reacting an alkyl cyclo pentane hydrocarbon with an olefin hydrocarbon in the presence of a catalyst, consisting essentially of HF or containing at least 85 percent by weight of HF as its essential active component. A temperature range of -20 to 200°C may be used.

U.S.P. 2,315,129. Alkylation Process. A. A. O'Kelly and R. H. Work to Socony Vacuum Oil Company.

Paraffins are alkylated with olefins in the presence of an alkylation catalyst and a hydrogenation catalyst. Preferred alkylation catalysts are metal chlorides and fluorides which are solid, stable compounds at temperatures above 600°F. and pressures above 2000 pounds, with special preference given to chlorides and fluorides of the alkaline earth metals. Such catalysts can alkylate either normal- or iso-paraffins. The amount of hydrogenation catalyst associated with the alkylation catalyst may vary from 0.5 to 10 percent. The alkylation operation is conducted in the same manner as if only alkylation catalysts were present. However, a larger yield is obtained or a lower temperature may be used to obtain the same yield as with alkylation catalysts alone. A preferred combination catalyst comprises fluorspar and chromium oxide. Carriers may be used. Temperatures between 800 and 900°F. and pressures above 2000 pounds are recommended.

U.S.P. 2,315,197. Method of Preparing Alkylated Hydrocarbons from Normal-Paraffinic Hydrocarbons. A. R. Goldsby and K. Korpi to The Texas Company.

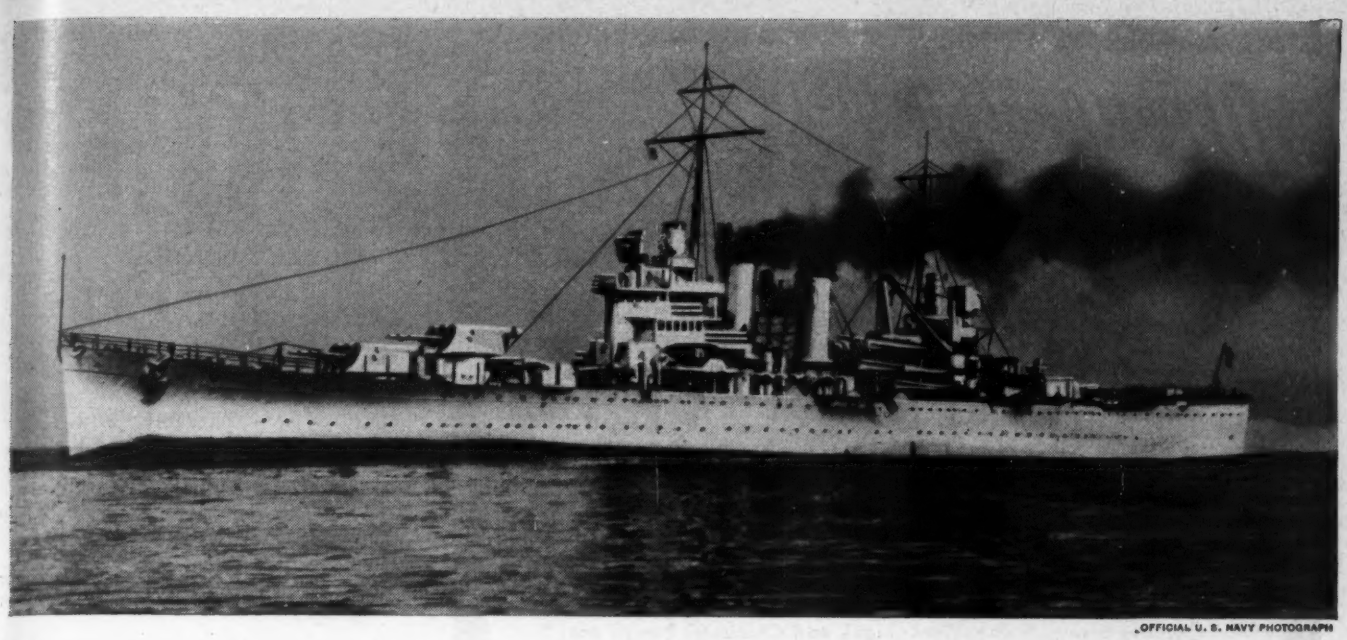
Normal-butane is isomerized and the i-butane formed in mixture with unconverted n-butane is contacted with olefins under alkylation conditions. The normally liquid iso-paraffins formed are separated and n-butane is recycled to the isomerization step.

U.S.P. 2,316,108. Alkylation Process and Catalyst Therefor. R. F. Ruthruff.

Sulfuric acid as an alkylation catalyst can be promoted by addition of small amounts of heavy metal salts and mixtures thereof. The alkylation reaction rate is speeded up considerably. The concentrated sulfuric-acid catalyst should contain a selenium compound and a compound of at least one metal selected from the group consisting of nickel, silver and copper. A mercury compound may be present in addition to the others.

U.S.P. 2,317,694. Paraffin Alkylation Process. C. J. Ott to Shell Development Company.

Alkylation of open- and closed-chain paraffins is effected by reacting such paraffins in the presence of an alkylation catalyst with esters of organic acids having dissociation constants greater than 2x10-5 and most prefer-



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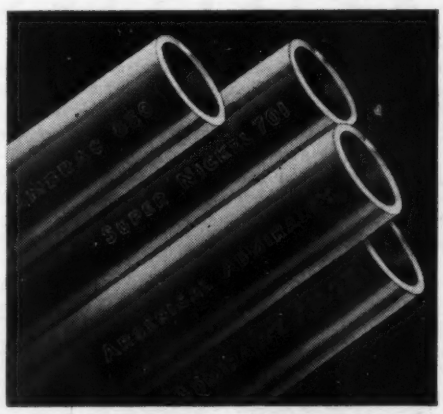

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U.S.P. 2,317,142. Manufacture of Motor Fuel. A. R. Goldsby to The Texas Company.

A combination isomerization and alkylation process is described.

U.S.P. 2,317,901. Conversion of Hydrocarbons. F. E. Frey to Phillips Petroleum Company.

A low-boiling n-paraffinic hydrocarbon heavier than methane is alkylated with an olefin hydrocarbon in the presence of concentrated HF as the sole catalytic alkylation component under suitable conditions. Such conditions for a stream containing predominantly n-butane are 400 to 500 pounds pressure and a temperature of 150 to 300°F. The amount of olefin in the mixture exceeds at no time the equivalent of 10 mol percent of the total hydrocarbons present.

U.S.P. 2,318,765. Treatment of Hydrocarbons. G. Egloff to Universal Oil Products Company.

Hydrocarbon oil is cracked in the presence of $AlCl_3$ to form substantial amounts of i-butane and normally gaseous paraffins are decomposed to form paraffin-olefin mixtures. These and the i-butane are commingled and fractionated to remove a light fraction comprising essentially hydrogen and methane. The remaining mixture of 2 to 4 C-atom hydrocarbons containing both olefins and i-butane is subjected to alkylation in the presence of a catalyst such as H_2SO_4, HF, BF_3 with HF or with F as a promoter or $AlCl_3$ with HCL as a promoter, generally at a temperature of —15 to 200°F. and under sufficient pressure to keep a substantial proportion of the reacting hydrocarbons in liquid phase. A calcined composite of an acid of phosphorus and a generally siliceous absorbent at a temperature of 60° to 900° F. and under a pressure of 1000 to 3000 pounds can also be used as a catalyst.

U.S.P. 2,318,781. Treatment of Hydrocarbons. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

Iso-paraffins are alkylated with olefins in the presence of a solid composite catalyst which is prepared by heating a mixture of $AlCl_3$ and a granular supporting material such as carbon, diatomaceous earth, silica, clays, fuller's earth, montmorillonite, etc., at elevated temperatures and pressures until the chloride has been adsorbed into the pores of the support. Temperatures of

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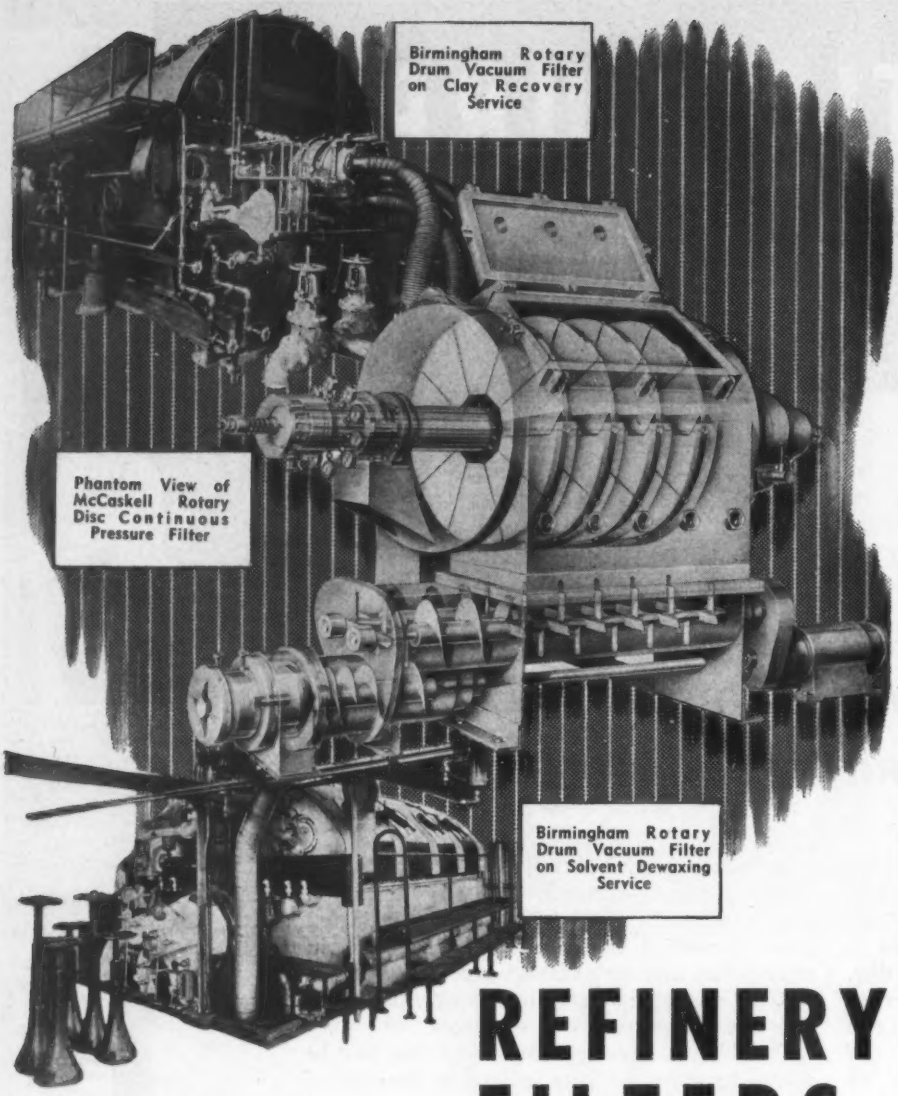

Birmingham Rotary Drum Vacuum Filter on Clay Recovery Service
Phantom View of McCaskell Rotary Disc Continuous Pressure Filter
Birmingham Rotary Drum Vacuum Filter on Solvent Dewaxing Service

REFINERY FILTERS

BIRMINGHAM Refinery Filters are specifically designed for the different process requirements. That this principle is correct is demonstrated by the fact that 38,400 bbls. per day of a total licensed MEK solvent dewaxing capacity of 39,000 bbls. per day in the U. S. is handled on Goslin Birmingham Solvent Dewaxing Filters.

The McCaskell Rotary Disc Continuous Pressure Filter makes available, now—for the first time, continuous pressure filtration with continuous automatic discharge of the dry cake to atmospheric pressure level. Specifically designed for the continuous and automatic removal of decolorizing clays from finished oil in contacting plant service.

The Birmingham Rotary Drum Vacuum Filter has pioneered the way in clay recovery plants for the "deoiling" of high oil content decolorizing clay cakes as discharged from the finished oil filters, and the washing of the reactivated clays for repeated use.

The Birmingham Rotary Drum Vacuum Filter; successor to this Company's Vallez Filter, the original solvent dewaxing filter; has been universally accepted as the American refinery standard for low dewaxing differential solvent dewaxing. Extremely shallow compartment drainage construction with the (patented) BIRMINGHAM drum compartment flushing and DriCake discharge attachments permit of sharp separation of filtrate and wash and a dryer wax cake discharge for important processing advantages.

Bulletins describing the above filters will be mailed upon request.

GOSLIN-BIRMINGHAM MFG. COMPANY

Chicago, Illinois · New Orleans, La. · **BIRMINGHAM 1, ALABAMA** · 350 Madison Ave., New York 17, N. Y. · Seattle, Washington · San Francisco, Calif.

about 250°C and a pressure of 25 atmospheres are suggested.

U.S.P. 2,320,199. Hydrocarbon Conversion. B. Sellmeyer to The M. W. Kellogg Company.

An alkylation process for the treatment of raw materials containing reactants desired for the process and in addition hydrocarbons which are lower boiling than the reactrants is described. The low boiling hydrocarbons are utilized in the reaction zone to effect the necessary cooling and are then eliminated by fractionation treatment of a mixture which contains the maximum concentration of these light hydrocarbons, thus reducing to a minimum the apparatus requirements of the process and the consumption of energy. Sulfuric acid is used as catalyst.

U.S.P. 2,320,336. Alkylation of Hydrocarbons. F. H. Bruner and W. E. Skelton to The Texas Company.

The invention contemplates a process of subjecting olefins and iso-paraffin hydrocarbons to reaction in the presence of a liquid alkylation catalyst such as concentrated sulfuric acid, wherein the olefin hydrocarbons are first absorbed in a separate body of catalyst under conditions such that alkylation and/or hydropolymerization do not occur, at least not to any substantial extent. Thereafter, the olefin hydrocarbons absorbed in the catalyst are subjected to contact with i-paraffinic hydrocarbons under conditions conducive to alkylation. It is desirable to avoid absorption of ethylene in the acid catalyst. C_3 and C_4 olefins can be absorbed at low temperatures of the order of 0°F.

U.S.P. 2,322,664. Production of Motor Fuels. R. P. Russell to Standard Oil Development Company.

In the alkylation of iso-paraffins with mono-olefins under alkylation reaction conditions in the presence of a mineral acid catalyst of alkylating strength, the improvement is claimed which comprises admixing an aromatic hydrocarbon with the said acid prior to catalyzing the alkylation reaction with said acid.

Louisiana Plant to Produce Specialties

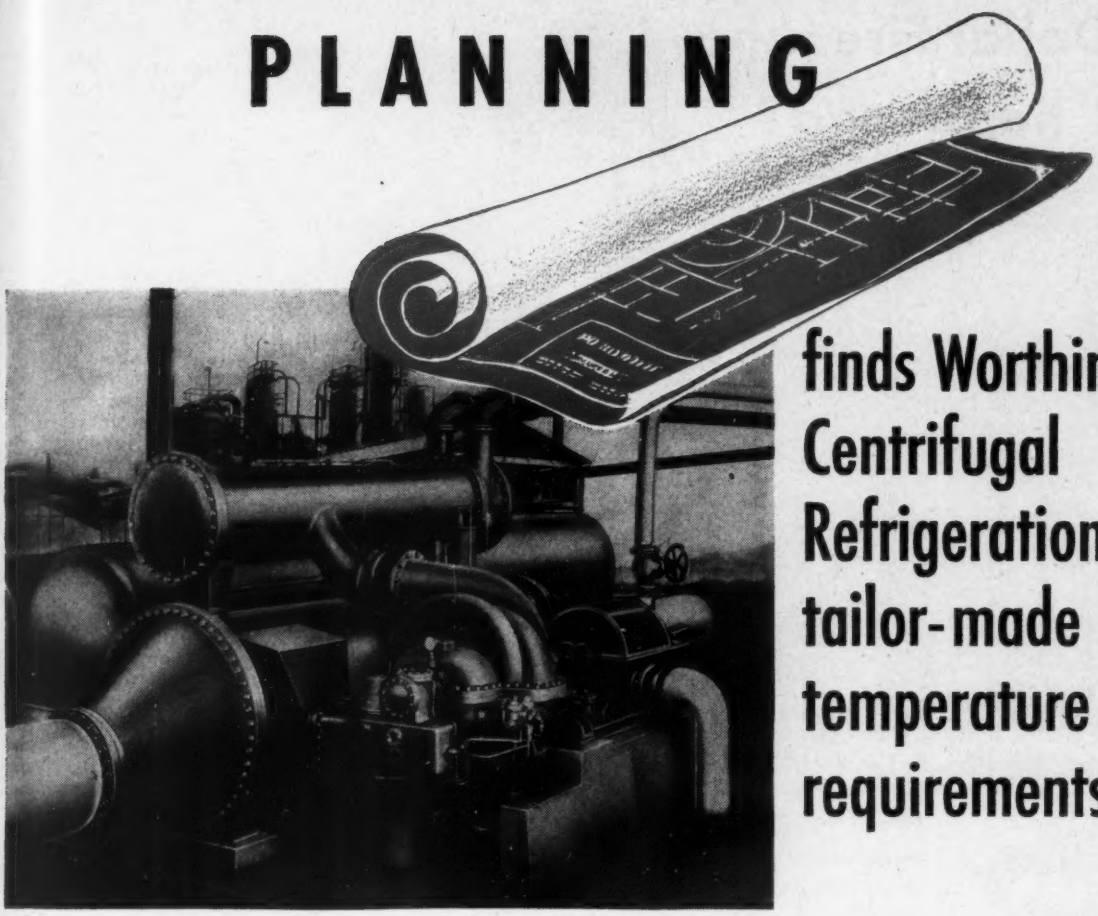
With the enlargement and revamping of the refining plant of River Petroleum Corporation, Belle Chase, Louisiana, the unit will be equipped to produce such petroleum specialties as Sulfonates, naphthenic acids and asphalts along with conventional and aviation lubricants.

Alterations are under the supervision of Harold F. Bottomley, chief engineer, who came to this post from a similar position with Cosden Petroleum Corporation, Big Spring, Texas. F. R. Redfern is general manager and Arnold Bondi is chief chemist. F. M. O'Connor is president.

L. E. Hebel Becomes Shell Research Head

L. E. Hebel has been promoted to research director of the laboratory of Shell Oil Company at Wood River, Illinois. Previously he was a research engineer in charge of the engine laboratory. He is a graduate of Wisconsin University and went with the Shell organization in 1928.

ALKYLATION PLANNING



finds Worthington Centrifugal Refrigeration tailor-made to its temperature control requirements

And naturally so, since the Worthington equipment designs were engineered for the particular requirements of this refinery application in the pioneer stages of the process development.

The experience of Worthington engineers in equipping the plants to go into early production has been reinforced in subsequent experience with others. So much so, that they are in an exceptional position to collaborate with the industry's specialists who may have further plants, or further advances in plant or process design under discussion at this time. **Worthington Pump and Machinery Corporation,** Refrigeration and Air Conditioning Division, Harrison, N. J. CA 9-39

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AND AIR CONDITIONING EQUIPMENT

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Scene: *a large refinery.*

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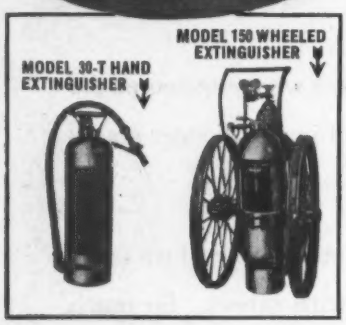
duGas



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FREE—New chart showing characteristics of all types of approved hand fire extinguishers. Copy sent free on request.

For further details and priority information, write today!

DUGAS ENGINEERING CORPORATION

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OWNED AND OPERATED BY ANSUL CHEMICAL COMPANY

Southwest Refiners May Increase August Runs

Unlimited throughput of refining plants of the Southwest has been approved by PAW as a means of building stocks of gasoline and heating oils for the Middle West and Atlantic Coast areas. The only restriction left on refiners is that of crude oil supplies, since the output of District 3 remains at 1,410,000 barrels daily, identical with July.

Refiners are privileged to get additional crude oil from West Texas, Southwest Texas and from New Mexico.

In explaining the action Ralph K. Davies, deputy administrator, said:

"Under the August crude allowables the refineries will continue making the maximum quantity of war products possible. The ceiling unlimited provision will enable refineries to increase their gasoline and heating-oil inventories.

"How many additional barrels a day can be run, over the 1,410,000-barrels-a-day allotment, cannot be determined at this time. It will depend upon the transportation facilities that can be made available. Transportation in the Southwest is still tight. We believe, however, that the quantity of additional crude runs will be appreciable."

During August, refiners may obtain crude oil from their usual sources so long as they keep within the quotas established in July. Additional runs, under the ceiling unlimited provision, however, must be oil obtained either from West Texas or New Mexico fields.

Refiners in the Corpus Christi area are also permitted to obtain their additional oil from the Southwest Texas fields.

Davies said regulation of the source of additional crude oil is necessary because other oil fields in the Southwest are now producing oil at maximum efficient capacity and cannot be stepped up without overproducing the fields, while the fields of West Texsa, New Mexico, and Southwest Texas can increase current daily production without affecting the underground reserve.

Pennsylvania Association To Study Lubricating Oils

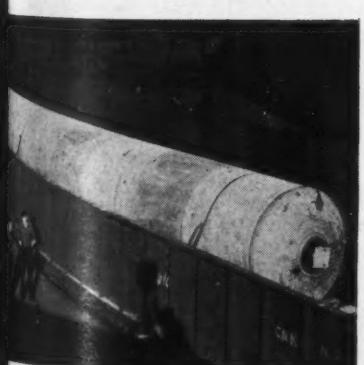
Expansion of the research program at the Petroleum Refining Laboratory in State College to include engine tests on lubricating oils was recommended by the Technical Advisory Committee of the Pennsylvania Grade Crude Oil Association recently. The group, which is made up of technical men in the refinery members, plants, also recommended that the current work at the petroleum refining laboratory be continued and intensified, with specific reference to certain features involving the improvement of Pennsylvania motor oils.

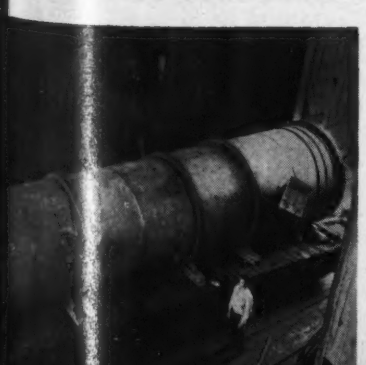
The committee was asked to study the problem and make recommendations for expanding the research program. This action was taken by the association's directors following the annual meeting held in Pittsburgh last month. The directors adopted a program for broadening and making more effective the work of the association, and the question of expanding the research program at State College was one of the points. A far-reaching program of research in the production of oil also has been set up, and a director for this work will be appointed.

THE acid resistance of glass-lined steel equipment plus its ability to withstand elevated pressures is usually suited to those companies using catalyst towers for vapor phase isomerization. Glass-lined agitating equipment has similar advantages for liquid phase isomerization.

Glass-lined steel is resistant to all acids (except HF) in any concentration or at any temperature, hence is comparatively unaffected by the aluminum chloride and free chlorine present in this phase of the process of converting butane to iso-butane in the manufacture of high-octane aviation gasoline. The same applies in the process of alkylation with concentrated sulphuric acid.

In addition to the substantial money saving, due to greatly increased equipment life, time is saved by eliminating replacement of a production line item. We suggest that if you have an acid corrosion problem it will be distinctly to your advantage to investigate the possibilities of glass-lined steel. Its services to the chemical field are a matter of record. Our engineering department is at your service to work with you on your problem.





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Glass-lined absorption towers

Glass-lined steel absorption towers with diameters ranging from 3 inches to 4 feet, with varying heights depending on the number of sections used, are now available for 300 lbs. per square inch internal working pressure, and with permissible temperatures up to 650° F., depending on conditions.

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SCIENCE AND TECHNOLOGY

Abstracts prepared in co-operation with the

PETROLEUM REFINER

by

THE LESLIE LABORATORIES

Traver Road, Ann Arbor, Mich.

under the supervision of

DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical And Chemical Data

Thermal Data. XVI. The Heat Capacity and Entropy of Isopentane. The Absence of a Reported Anomaly, G. B. GUTHRIE, JR., AND H. M. HUFFMAN, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1139-43.

The heat capacity of isopentane was measured over the temperature range 13 to 300°K. The melting point and heat of fusion of isopentane were determined. The authors believe that the results of their investigation indicate that certain anomalous results reported by Aston are not characteristic of isopentane. The entropy of liquid isopentane at 291.16°K., calculated from the data of the experimental work, is 62.24 + 0.10 cal. degree $^{-1}$mole^{-1}. It is suggested that thermochemists should check their methods so that the accuracy assigned to the experimental results will have a real significance. The data secured in the course of the work are presented in detail in tabular form.

The Heat Capacity and Entropy, Heats of Transition, Fusion and Vaporization and the Vapor Pressures of Cyclohexane. The Vibrational Frequencies of Alicyclic Ring Systems, J. G. ASTON, G. J. SZASZ AND H. L. FINK, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1135-9.

The heat capacity of solid and liquid cyclohexane was measured from 12.6 to 293.8°K. The equilibrium temperatures of the transition and the fusion, together with their heats, were determined. The heat of vaporization was determined at 298.16°K. The experimental vapor pressure equation over the range 280 to 294°K. was used to calculate the value of the heat of vaporization at 298.10°K. Comparisons of the experimental entropy with that calculated from statistical and molecular data afford a means to assign the lowest vibrational frequencies. The result which was based on a "chair" configuration for the cyclohexane molecule is in good agreement with previous assignments on similar molecules. The data secured in the experimental work are presented in detail in tabular and, partially, in graphical form.

Heat Capacities of Hydrocarbon Gases, D. R. STULL AND F. D. MAYFIELD, *Ind. & Eng. Chem.* **35** (1943) pp. 639-48.

The method of calculating gaseous heat capacities from spectroscopic data as developed by Bennewitz and Rossner, and modified by Dobratz, has been extended to a wider temperature range. By reassignment of certain frequencies, the method has been brought into closer agreement with the data in the literature on heat capacities; it has also been extended to acetylene derivatives. A table of solutions of the Einstein function for one degree of freedom is included. A table of bonding frequency contributions to the molar heat capacity for temperatures from 250° to 1500°K. is presented. The calculated heat capacities of twenty-nine hydrocarbons over the temperature range 250° to 1500°K. are compared with previously published data and show an average difference of + 4 percent. The molar heat capacities of the hydrocarbons are given in tabular form at 50° temperature intervals. A bibliography of 29 references is included.

Equilibrium Still for Miscible Liquids, C. A. JONES, E. M. SCHOENBORN, AND A. P. COLBURN, *Ind. & Eng. Chem.* **35** (1943) pp. 666-72.

The design of distillation and other contacting equipment requires reliable vapor-liquid equilibrium data. A new apparatus for determining vapor-liquid equilibria of miscible mixtures is described. This comprises a residue chamber, a condensate chamber, and a flash boiler to vaporize the stream returning from the latter to the former. This arrangement ensures that a uniform concentration exists in the residue chamber at equilibrium. Vapor-liquid equilibrium data at 760 mm. pressure are presented for ethylene dichloride-toluene and ethanol-water. Isothermal data at 50° and 60°C. are presented for the latter system. The consistency of the results by use of this apparatus is shown by the close agreement of the ethylene dichloride-toluene data with Raoult's law. The data on ethanol-water at one atmosphere pressure are in good agreement with those of Carey and Lewis. Evaluation of the isothermal data on ethanol-water in terms of the van Laar equations indicates that these equations do not fit this system exactly, although they are a reasonable approximation. The activity coefficients and the van Laar constants, furthermore, show a negligible change with temperature over the range 50° to 60°C. in agreement with predictions from available heat of solution data. The data secured in the experimental work are presented in some detail in tabular and graphical form.

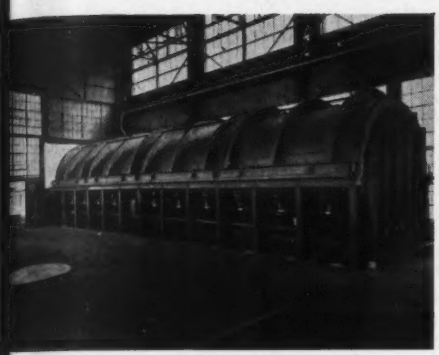
Correlating Fluid Viscosity, A. S. SMITH AND G. G. BROWN, *Ind. & Eng. Chem.* **35** (1943) pp. 705-11.

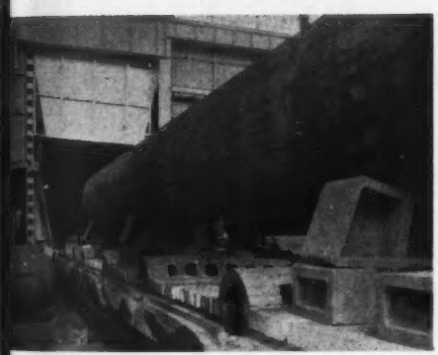
The viscosities of ethane and propane in the range 100 to 5000 pounds per square inch pressure and 15° to 200°C. were determined by use of the rolling-ball viscometer. The data secured are presented in some detail in tabular form. An equation derived from the theorem of corresponding states was applied to viscosity-temperature data on gases and liquids at atmospheric pressure, under saturated conditions and under pressure, for the purpose of determining the value of this method for extrapolating viscosity values. The equation was found applicable to homologous series and diatomic gases, the viscosities of which can be represented by curves specific for each series. A chart is given showing the viscosities of the normal paraffin hydrocarbons, except methane, and their solutions. This serves to extend viscosity data covering this series for reduced pressures up to 10 and reduced temperatures from 0.65 to 1.5.

Adsorption of Propane and Propylene by Silica Gel and Metallized Silica Gel, L. H. REYERSON AND M. R. CINES, *J. Phys. Chem.* **46** (1942) pp. 1060-8.

The adsorptions of propane and propylene on silica gel and on silica gel metallized with palladium were meas-

Complete Facilities





READY FOR YOUR PRESSURE VESSEL REQUIREMENTS

Since 1930 Combustion Engineering has built thousands of welded pressure vessels of every size and variety, a large percentage for use by refineries. This work has included some of the largest and heaviest pressure vessels ever built. It has also involved fabricating and welding problems of the most exacting nature—problems that can be dealt with successfully only by an organization possessing exceptional facilities and experience. During the present war C-E facilities have been greatly expanded and are now in a position to handle a far greater volume of pressure vessel work than before, and with new benefits to the purchaser. For C-E is able to apply to this work not only the highly developed knowledge and skill acquired as pioneers in the fusion welded fabrication of carbon steels and steel alloys, but also the improved methods and techniques developed to produce a vast volume of war work.

A-747

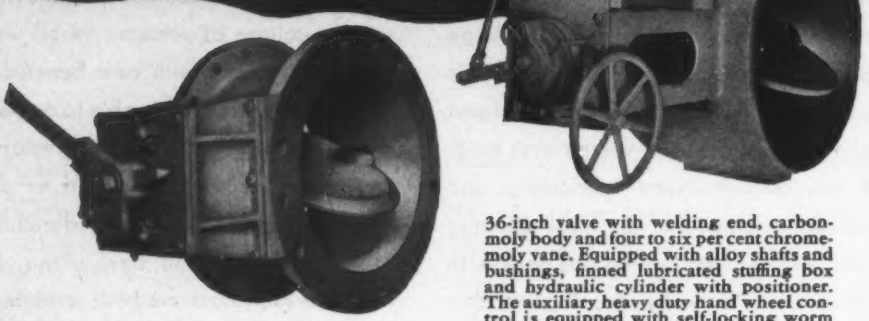
Annealing

For stress relieving pressure vessels C-E has several annealing furnaces of various types and sizes. One of the largest of these is shown by the lower view where a large vessel is ready to roll into the furnace.

Finished Refinery Vessels

The great variety of welded pressure vessels built by C-E for refinery use is suggested by this view of a C-E shop. Conspicuous in the foreground are (left to right) an atmospheric tower, a stripper tower, a 70,000 gallon butane storage tank, a hot oil stripper. Other partially-finished refinery pressure vessels appear in the background.

Unequaled Flow Characteristics Low Pressure Loss and Maintenance



36-inch valve with welding end, carbon-moly body and four to six per cent chrome-moly vane. Equipped with alloy shafts and bushings, finned lubricated stuffing box and hydraulic cylinder with positioner. The auxiliary heavy duty hand wheel control is equipped with self-locking worm and gear and declutching unit.

Standard 125 lb hand lever operated valve. Can be equipped with hand wheel, chain lever or chain wheel. An extension shaft is provided for inaccessible locations.

15 to 900 psi
for air, gas, steam, liquids and semi-solids

A glance at the design of an R-S Butterfly Valve indicates that there is practically no restriction to the flow. The carefully-machined body bore and streamlined vane offer minimum resistance. In fact, the flow conditions are similar to those produced in a venturi tube with high pressure recovery on the downstream side.

It is apparent that the pressure loss in a wide open R-S Butterfly Valve is considerably less than in most conventional types of wedge gates. Add to this the fact that there are no pockets to collect sediment. When the vane approaches a closed position, the valve tends to clean itself.

Shut-off is accomplished by the beveled vane which wedges tight against the valve body. Four to six revolutions of a hand wheel completely open or close the valve vane. Accurate control and shut-off by hand or automatic equipment is a simple matter.

Where hard wear and severe stresses are encountered, the use of R-S "A" metal will produce outstanding results and increased service. Specify R-S Butterfly Valves for reduced maintenance.

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ured at -25°, 0° and 35°C. Propylene is more strongly adsorbed by the metallized surface than by the plain gel, and is more strongly adsorbed than the paraffin. Results of the study are in reasonably good agreement with the theory of Brunauer, Emmett and Teller.

Chemical Compositions And Reactions

Preliminary Examination of Some Turner Valley Crude Oils, MAY, MINERS AND SPINKS, *Can. Jour. Res.* **21** (1943) pp. 73-9.

Eight crude oils from the Turner Valley field were examined and distillation, refractive index, and specific refractivity data were obtained. Following a Hempel distillation, the crude oil was fractionated in a steel column three feet long and 2 inches in diameter, packed with jack chain. The cuts from this distillation were fractionated in a 1-inch Stedman column, samples being taken at 1°C. intervals or less. Refractive index and density were taken on each cut. Specific refractivity was calculated. All the oils contained the same compounds, though in somewhat different proportions. The cuts were produced that either contained more than 50 per cent of a particular hydrocarbon, or that, at most, contained three or four hydrocarbons. Among the hydrocarbons found were isopentane, n-pentane, 2-methylpentane, n-hexane, metehylcyclopentane, cyclohexane, toluene, branched heptanes, dimethylcyclopentanes, n-heptane, methylcyclohexane, branched octanes, dimethylcyclohexanes, n-octane, ethylbenzene and the xylenes, and n-nonane.

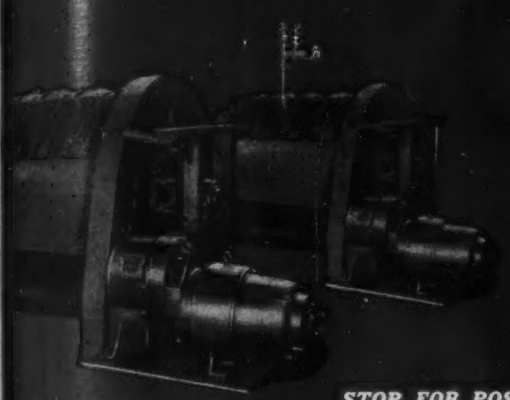
Apparatus for Purification of Hydrocarbons by Recrystallization, J. L. KEAYS, *Ind. & Eng. Chem., Anal. Ed.* **15** (1943) pp. 391-2.

In the course of an investigation of the properties of normal paraffin hydrocarbons, it was necessary to synthesize several homologs and to obtain them in the highest possible state of purity. Purification was accomplished mainly by repeated recrystallization from glacial acetic acid, since the higher paraffin homologs are slightly soluble in this acid at boiling temperatures and almost insoluble at room temperatures. The apparatus used for the purpose is described, as well as the procedure followed.

Polymerization of Butylenes with Aluminum Silicate Catalyst. II. B. A. KAZANSKII AND M. I. ROZENGART, *J. Gen. Chem.* (U.S.S.R.) **12** (1942) pp. 246-54.

The authors investigated the polymerization of isobutylene, the isomerization of diisobutylene and polymerization of n-butylene. By use of the Gayer catalyst isobutylene was polymerized at temperatures from 130° to 295°C. The dimer fractions were hydrogenated and fractionated for identification. Isomerization was found to accompany polymerization. Of the isomeric dimers produced at 130°, only 2 were found: 2,2,4-trimethylpentane, and 2,2,3-trimethylpentane. As the temperature of the reaction is raised the latter isomer is formed in greater amounts, with a maximum of 60-65 percent at 200°C. At 295°C. the products found were 2,2-dimethylhexane, 2,3,3-trimethylpentane

BU UNITED STATES WAR BONDS AND STAMPS



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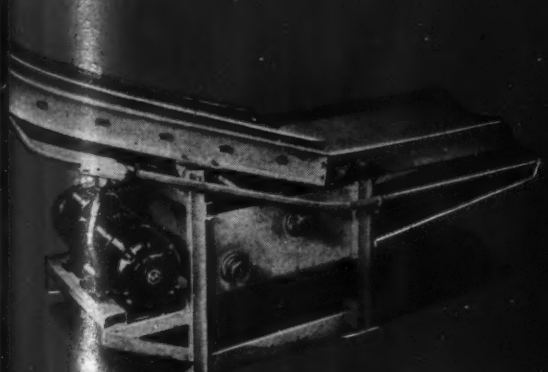

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STOP FOR SAFETY
Reduce the hazard of injury to workmen or damage to equipment which might cripple vital production

ONE-MAN OPERATION Helps Solve Man-Power Problem in Refineries

Every Roto Tube Cleaner you put to work in your plant enables you to release one man for other productive work. A simple air valve on the Roto motor permits one man to operate the cleaner entirely by himself. This not only saves a helper, but eliminates delays caused by having to signal the helper to turn air off and on between every tube cleaned. The powerful Roto motor and keen cutter heads make short work of hard carbon and scale or soft, gummy deposits. Roto offers a wide variety of air- and water-driven cleaners for any cleanable tube from ½" to 12" I.D. Leading refineries enjoy the time- and labor-saving features of Roto Tube Cleaners. How about yours? Write today.

Roto Model 130 air-driven motor with swing-frame head and air valve for one-man operation in 3¼ inch curved tubes.

Write for Details

The ROTO Company

145 Sussex Ave., Newark, N. J.

ROTO Tube Cleaners

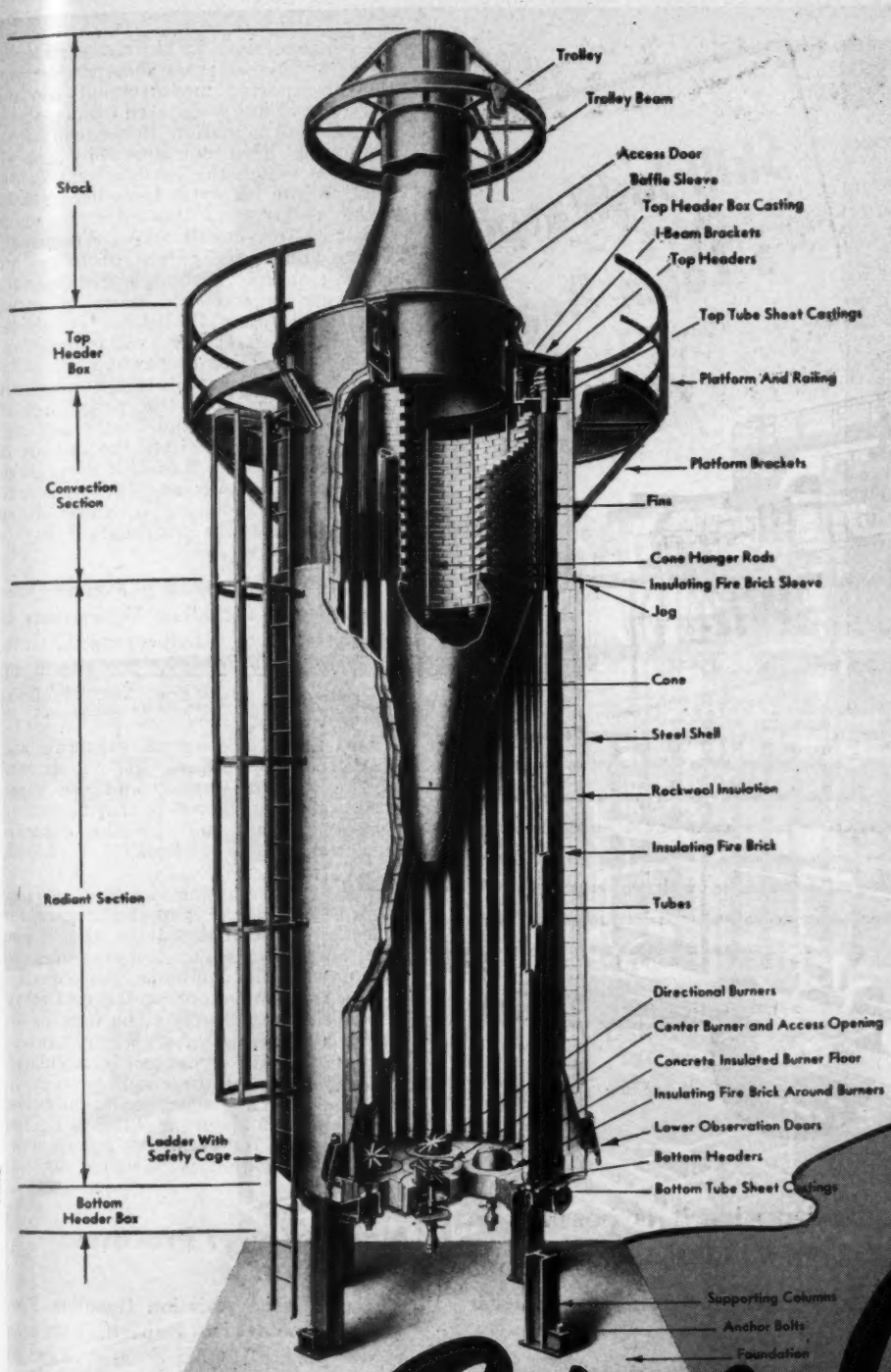
and 2,3,4-trimethylpentane. n-Butylene, polymerized on the Gayer catalyst at 200° and 300° respectively gave 14.8 and 14.1 percent of liquid products, which contained 3,4,4-trimethyl-2-pentene. The authors feel that the polymerization of butylenes at high temperatures proceeds in a complex manner, accompanied by isomerization and formation of isomeric octenes. Calculation of the equilibrium constant must take into account the isomerization of the reaction products. The equilibrium constant, from data at 4 temperatures, and the heat of dimerization of isobutylene into diisobutylene were calculated.

Thermal and Catalytic Decomposition at High Pressures, V. HAENSEL AND V. N. IPATIEFF, *Ind. & Eng. Chem.* 35 (1943) pp. 632-8.

The decomposition of cyclohexane at high temperatures and pressures, with and without alumina, was investigated. In the absence of alumnia, using a chrome-molybdenum steel reaction tube, methylcyclopentane is the isomerization product. The composition of the exit gas, formed both in the presence and absence of alumina, indicates that cyclohexane ring splits at two points to give ethylene, propylene, and butylene as the primary products. At the same time cyclohexane dehydrogenates to benzene and hydrogen. The hydrogen made available destructively hydrogenates the olefins formed during the ring splitting. The composition of the gaseous products does not correspond with that predicted by the Rice mechanism. The liquid products contain cyclopentane, methylcyclopentane, cyclohexene, methylcyclopentenes, benzene, toluene, diemthycyclohexanes, m-xylene, and phenylcyclohexane. The postulated mechanisms for cyclohexene and methylcyclopentene include dehydrogenation of cyclohexane to cyclohexene followed by isomerization to methylcyclopentene, because it was found that methylcyclopentane does not isomerize to cyclohexane while the reverse reaction proceeds readily. The mechanisms proposed for compounds such as alkylbenzenes and alkylcyclohexanes involve alkylation of benzene and cyclohexane by olefins and paraffins formed during ring splitting. Alkylation takes place under the experimental conditions. The interaction of benzene and propylene produces toluene and m-xylene in small yields, but when either benzene or propylene is reacted separately, no toluene or m-xylene is formed. Further alkylation, using toluene and propylene as well as toluene and propane, produces higher alkylbenzenes. Presence of an olefin increases the yield of diphenyl from benzene since the olefin acts as a hydrogen acceptor. The apparatus used in the work is described, and the data are presented in some detail in tabular and graphical form.

The Catalytic Hydrogenation of Benzene Over Metal Catalysts, P. H. EMMETT AND NIS SKAU, *Jour. Am. Chem. Soc.* 65 (1943) pp. 1029-35.

As part of his multiplet theory of catalysis, Balandin in 1929 postulated that a metallic catalyst, in order to be active at low reaction temperatures in the hydrogenation of benzenes to cyclohexane, must possess developed crystal faces with a triangular configuration and with lattice dimensions standing in a definite relation to the dimensions of



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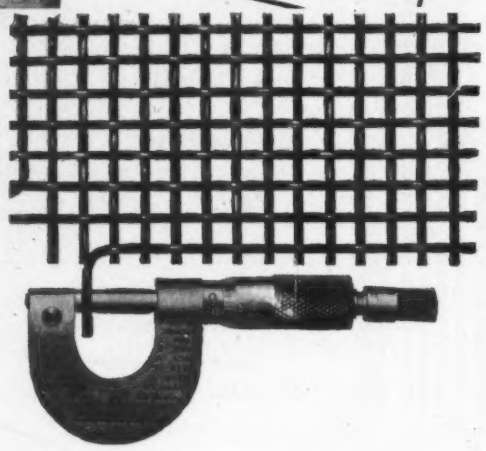

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the benzene ring. In their experimental work the investigators showed that previously reported measurements on the inactivity of body-centered iron catalysts for the hydrogenation of benzene below 200° have been confirmed by experiments in which the surface area of the inactive iron catalysts have been shown to be as large as that of very active cobalt or iron-cobalt alloys. Copper catalysts substantially free of nickel are inactive at 200° although their surface areas are several fold those of active cobalt catalysts. Palladium is active; silver is inactive; Two palladium-silver alloys have activities per unit of palladium content that decrease markedly with a decrease in the percentage of palladium. Having dimensions and surface configuration within the "square of activity" of the Balandin hypothesis seems to be a necessary but not a sufficient prerequisite to a metal being catalytically active for benzene hydrogenation below 200°C.

The Thermodynamics of Styrene (Phenylethylene), including Equilibrium of Formation from Ethylbenzene, L. GUTTMAN, E. F. WESTRUM, JR., AND K. S. PITZER, *Jour. Am. Chem. Soc.* **65** (1943) pp. 1246-7.

The heat capacity of styrene was measured from 15 to 300°K., as well as the heat of fusion, and the vapor pressure. The latter is represented betweten 0 and 60° by the equation $\log_{10}$Pmm.Hg = $-2604.67T^{-1} - 2.57692 \log_{10}T + 15.90485$.

Since the reaction forming styrene from ethylbenzene is of importance, the investigators calculated the equilibrium constant at various temperatures by thermodynamic methods. An equation is given for the vapor pressure of ethylbenzene from 0 to 60°. The heat of the reaction of dissociation of ethylbenzene into styrene and hydrogen is calculated. Available data on the cracking of ethylbenzene indicate that near-equilibrium yields are obtained at 425-550°C., but not at higher temperatures, where, however, the situation is obscured by side reactions.

Manufacture: Processes And Plant

High-Octane Aviation Gasoline Program Continues to Expand, EDITORIAL STAFF REPORT, *Chem. & Met. Eng.* **50** (1943) pp. 129-32.

The scheduling of the production of aviation gasoline from 24,000 barrels per day in the spring of 1941 to the present time is reviewed, and it is shown how lack of foresight retarded the production of facilities. It was only in October 1941 that those in authority agreed to the doubling of the capacity of aviation gasoline to some 80,000 barrels per day. In December it was raised to 120,000 barrels per day. Further expansion to 180,000 barrels was authorized in February 1942, and to 240,000 barrels in March 1942. Additional productive capacity was authorized in May 1942. It was not until May 1942 that a semi-official estimate showed that by December 1943 the demand for 100-octane gasoline would be of the same general order of magnitude as the production that industry had already started to make, and this estimate was based on a then-obsolete plane program. Even in September 1942, the situation was still

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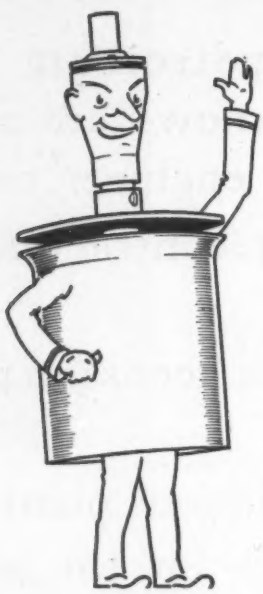

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such that no new official long range figures were available for 1944, and the Office of the Petroleum Coordinator had to make its own unofficial estimate based on information from the Aeronautical Board. This estimate indicated a requirement in 1944 almost double that estimated earlier in the year. Between February and April of this year the indicated requirements rose again sharply. The end is not yet in sight. Difficulties that were had by the oil industry in securing material, priorities and directives are reviewed. A flowsheet is included illustrating the processes related to the production of aviation gasoline from natural gas derivatives and a simplified flowsheet showing the derivation of the three most important war products from cracking plants of the petroleum industry: high-octane aviation gasoline,, synthetic rubber raw material, and toluene. Plants of the Standard Oil Company of Louisiana at Baton Rouge are briefly described.

Mixed Solvent Extraction. J. H. WIEGAND, *Ind. & Eng. Chem., Anal. Ed.* 15 (1943) pp. 380-3.

The methods of analytical geometry have been applied to the solution of four-component system problems with satisfactory results. To facilitate use of the method, the equilateral tetrahedron used by Hunter has been distorted to a tetrahedron of three isoceles right-angle triangle faces, which tetrahedron is placed on the x-y-z rectangular coordinate system. Equations have been derived in terms of general properties of liquid-liquid equilibrium systems. The introduction of the use of the intersection point of the tie lines on the extension of the base line of the phase triangle allows generalized equations to be derived for the solution of various problems. Additional equations have been derived that relate the above equations to the conditions of a specific problem. The resultant saving in time by this analytical procedure is large as against the graphical method of Hunter, especially if a number of problems are to be solved for the same system. The accuracy of the analytical method has been shown to be satisfactory. Its application to solvent refining is illustrated.

Benzene Poisoning in Industry, R. H. WILSON, *J. Lab. Clin. Med.* **27** (1942) pp. 1517-21.

The increased use of benzene in industry has added to the importance of handling benzene poisoning. The seriousness of poisoning from exposure, the need for constant medical supervision, the importance of early detection of absorption of the vapor, and preventive measures and treatment of patients with various degrees of intoxication are considered. The best index of benzene absorption is the blood count. 1104 people, employed in a rubber factory, were studied. They were exposed to concentrations of benzene vapors averaging approximately 100 parts per million for varying periods of time. Of the entire group, 7.5 percent showed slight absorption, and 2.2 percent showed marked absorption. Nine of the patients had severe aplastic anemia and three died.

Texas City Styrene Plant Gets Under Way, *Chem. & Met. Eng.* 50 (1943) p. 133.

The production of styrene in Mon-

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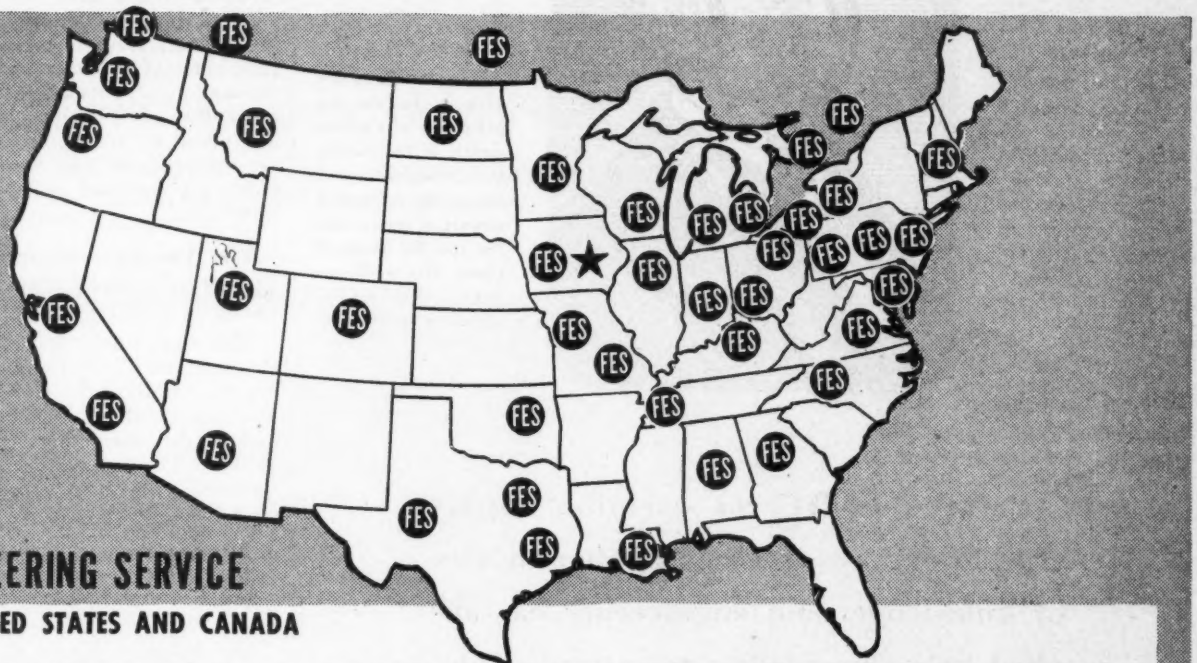

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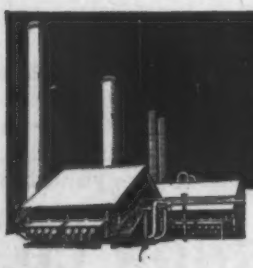

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santo Chemical Company's plant at Texas City is based on propane gas from nearby petroleum refineries and benzol from byproduct coke ovens. Propane is cracked to yield ethylene, then combined with benzene by catalytic alkylation to form ethyl benzene, which is dehydrogenated to produce styrene. The annual capacity of the plant is 50,000 tons. Three photographs showing the plant are included.

Production of Buna-S Synthetic Rubber, *Chem. & Met. Eng.* **50** (1943) pp. 140-3.

A flowsheet is given showing the conversion of ethyl alcohol to butadiene, the manufacture of styrene from benzene and ethylene, and the copolymerization of butadiene and styrene to make Buna-S. Fourteen photographs of the plant at Institute, West Virginia, are included. A brief description of the processes involved accompanies the flowsheet.

War Developments in the Petroleum Industry, E. V. MURPHREE, *Ind. & Eng. Chem.* **35** (1943) pp. 623-31.

The most important contributions of the petroleum industry to the war effort are the production of high-octane aviation gasoline, of synthetic toluene, and of the raw materials for synthetic rubber. The operations of super-fractionation, alkylation, isomerization, hydroforming, catalytic cracking and the manufacture of aviation gasoline and butadiene, are described briefly.

GR-S Rubber, J. A. LEE, *Chem. & Met. Engr.* **50** (1943) pp. 98-102.

The synthetic rubber plat at Institute, West Virginia, is described, including the units for making butadiene, styrene and the copolymer Buna-S. Butadiene is made from alcohol. Part of the alcohol is catalytically converted to aldehyde, which is then combined with alcohol and fed to the remaining converters. The reaction mixture is distilled, and 98.5 percent purity butadiene is obtained and stored in spheres holding 250,000 gallons. The equipment is almost entirely carbon steel. No stainless steel was used. Styrene is made by a process originally developed for the making of styrene resin. The raw materials are benzene and ethylene. The benzene is first treated to remove sulphur and sulphur compounds, principally thiophene. This is accomplished with sulphuric acid in batch agitators. The purified benzene is dehydrated by distillation and fed to continuous alkylation reactors where ethylene is added in the presence of a catalyst. Part of the benzene is converted to ethyl benzene and part to polyethyl benzene. Additional benzene is added and part of the polyethyl benzene is then reacted with fresh benzene to make ethyl benzene. Purified ethyl benzene is converted to styrene by a unique process that avoids the difficult separation of ethyl benzene from styrene by distillation. The styrene product has a purity of over 99 percent. The polymerization plant is of the standard design developed by the Engineering Design Committee of Rubber Reserve. Preparation of the materials, polymerization, coagulation procedure, filtering and drying are briefly

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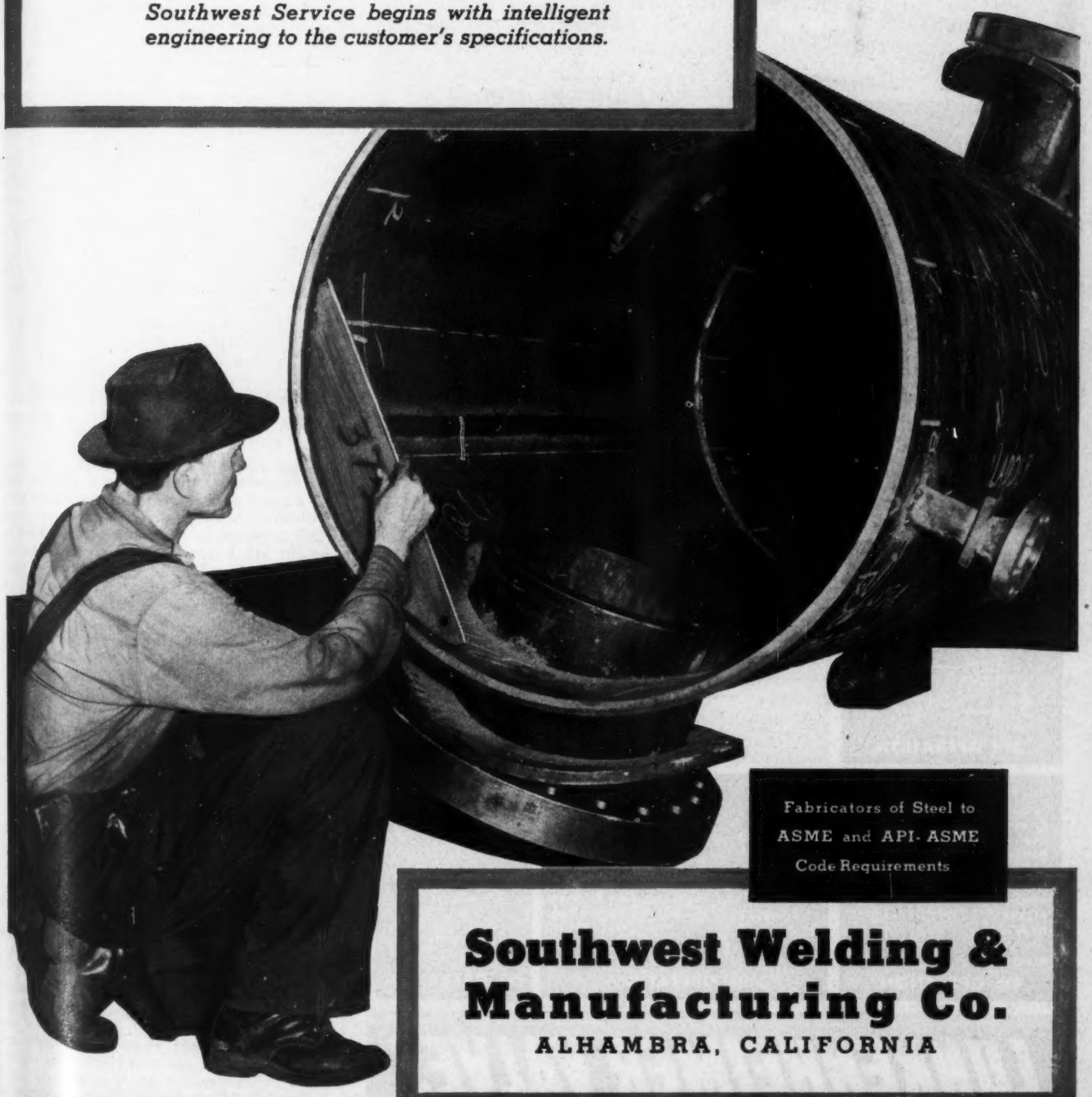

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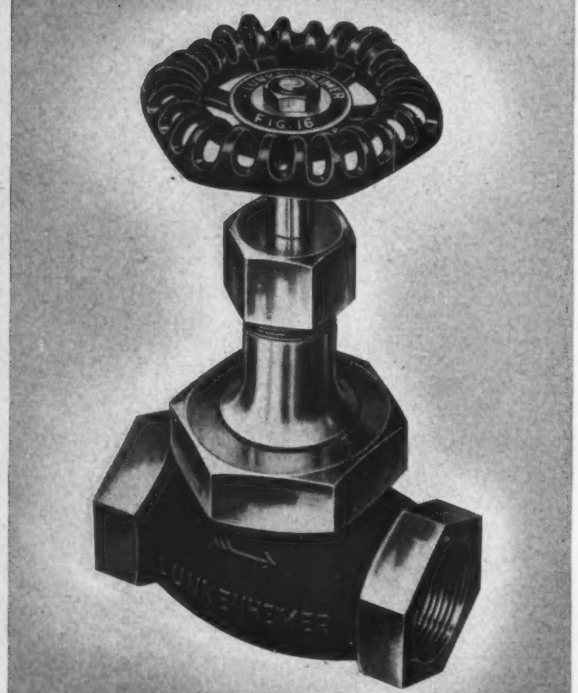

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Extension on bottom of hub should enter neck of body while regrinding
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5th OPERATION

6th OPERATION

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described. The article is illustrated with several photographs.

Products: Properties And Utilization

Colloidal-Fuel Development, J. G. COUTANT, *Southern Power & Ind.* 61 (1943) pp. 89-91.

Coal dust and oil failed to burn properly even though combined with a fixative in existing oil burners. Consideration was therefore given to a truly colloidal fuel. Powdered coal was purchased and reduced to a fineness such that it passed through a 30-mesh screen. It was weighed and sifted into an oil-mixing tank, filled with fuel oil. A motor-driven top-entering propeller-type mixer was used in the tank to mix the coal and oil, and steam and water coils were provided to permit securing the proper mixing temperature. The mixture so formed flowed by gravity into a colloid mill feed tank from which it was pumped to a horizontal colloid mill. The product from the colloid mill was delivered to a storage tank. The colloidal mixture had a fluidity equivalent to oil and contained 70 percent oil and 30 percent coal. The specific gravity was 1.11. The flame temperature from the colloidal fuel was approximately 150°F. higher than from bunker C oil. The fuel was tried in both direct and recirculating fuel oil systems. Four types of burners from three manufacturers were used. Operating data are presented in the article, as well as a drawing showing a full-sized colloidal fuel plant with a capacity of 600,000 barrels per year. The cost of such a plant was estimated at $125,000. It is suggested that large savings of fuel oil could be realized if industries adopted this system generally.

The Influence of Lubricating Oil Viscosity on Cylinder Wear, H. A. EVERETT, *S. A. E. Jour.* **51** (1943) p. 165.

The effect of viscosity of oils upon the wear of cylinders was determined by engine tests run under carefully controlled conditions. Six oils were used, each a blend in different proportions of bright stock and neutral from Pennsylvania crude oil. The engines used were of the L-head and air-cooled type. Twelve engines were used. Each was connected to a ⅓ horsepower synchronous motor. The temperature of the oil in the crankcase was maintained at 230°F., cylinder heads were at 450°F. Non-leaded gasoline was used. After an 8-hour engine run a 10-gram sample was ashed, the ash dissolved in hydrochloric acid and the iron estimated colorimetrically. It was found that the wear was inversely proportional to the kinematic viscosity of the oil.

Mean Molecular Weight of Bitumens, W. KIRBY, *Jour. Soc. Chem. Ind.* 62 (1943) p. 58.

The Barger method of determining molecular weights appears eminently suitable for bitumens, resins, oils, and fats. It is incorrect to talk of the molecular weight of such substances but it is permissible to describe the results obtained as the "mean molecular weight." The method is based on the experimental fact that non-ionized and non-associated solutions of equal molecular concentration are isotonic or exert equal vapor pressures. The procedure to

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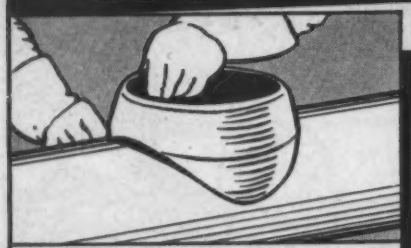

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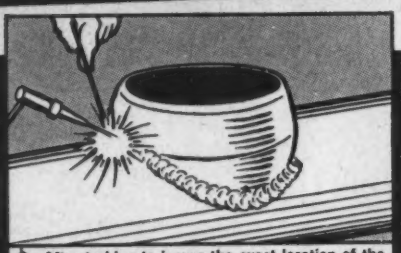
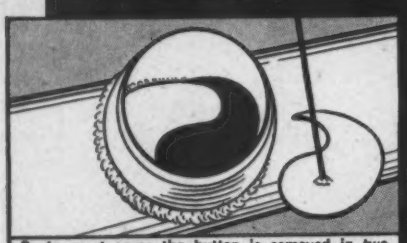
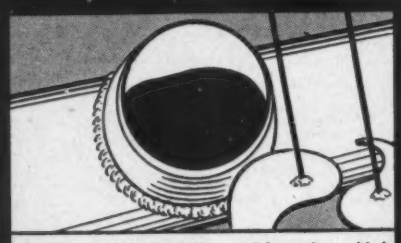


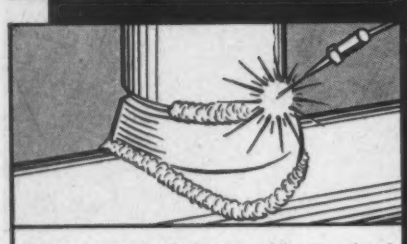
2—After tacking to insure the exact location of the W-T*, complete its installation by electric-arc or oxy-acetylene welding—following and filling the bevel at the base of the fitting.



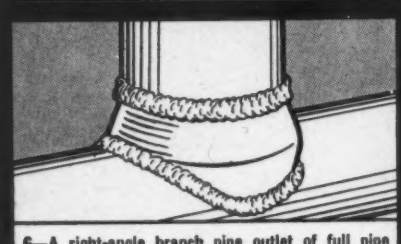
3—In most cases the button is removed in two sections with a torch after the WeldOlet or ThredOlet is installed—but where the outlet is smaller than 2", the hole should be cut in the main pipe first, using a drilling or hole saw.



4—This method of making a right-angle, welded branch pipe outlet insures a junction of full pipe strength—permits inspection of inside of junction—allows removal of slag and excess weld metal.



5—Branch pipe is attached by welding to outlet of fitting if WeldOlets or Socket-End WeldOlet has been used—or screwing into threaded outlet of fitting if a ThredOlet has been used.



6—A right-angle branch pipe outlet of full pipe strength has been made without the use of templets, without threading or fitting the main pipe and because of the patented design of the fittings—flow conditions have been improved.

3 Types Meet Every Need

Made of drop forged steel — to provide maximum strength. Available for all standard pipe sizes up to 24".

Branch pipe is attached to outlet of WeldOlet with plain, butt weld—to ThredOlet by screwing into threaded outlet of fitting—to Socket-End WeldOlet by weld around top of fitting after slipping branch pipe into outlet.

*WeldOlets-ThredOlets

Other Advantages

Lightweight compared to screwed or welding tees—saves metal—eliminates need for extra hangers and braces.

Elimination of exterior obstructions makes neater, more workmanlike installation, permits easier covering with insulation.

Adaptable to any and all types of piping systems—pre-fabricated or "on-the-job" assemblies—new construction or maintenance.

Suitable for all commonly used pressures and temperatures.

Initial cost is less in most cases than for other types of fittings to accomplish the same result. Installation savings run as high as 40%.

Forged Fittings Division

BONNEY FORGE & TOOL WORKS, Allentown, Pa.

WELDOLETS* THREDOLETS

TRADE MARKS - REG. U. S. PAT. OFF.

Welded Outlets for Every Piping System

be followed is described in some detail. Typical results are included. The mean molecular weight of a Mexican asphalt was found to be 715, that of Gilsonite, 1510. It is suggested that the method may be of use in the solution of such problems as whether the hardening of soft pitches on road surfaces is caused mainly by polymerization or by simple evaporation of the lower-boiling oils.

Effect of Petroleum Products on Buna S Vulcanizates, R. E. MORRIS, P. MITTKN, J. C. MONTERMOSO, AND T. A. WERKENTHIN, *Ind. & Eng. Chem.* **35** (1943) pp. 646-49.

Little information has been published concerning the solvent or oil resistance of Buna S. The lack of interest in the oil and solvent resistance of Buna S is occasioned by the fact that it is not intended for use where liquid hydrocarbons come in contact with it. However, in certain applications Buna S can have contact with gasoline or oils—for example, in tire treads, conveyor and drive belt covers, hose covers, and wire insulation. On the basis of certain published information it would be expected that Buna S would stand up as well, if not better, than Hevea rubber. Unfortunately this is not true. Buna S vulcanizates were found to suffer serious losses in tear resistance when exposed to the influence of petroleum products, particularly the more volatile ones. The conventional tests for swelling and loss of tensile strength in petroleum products are misleading when applied to Buna S vulcanizates because they give no indication of this failure. The coincidence of the following three conditions on the surface of a Buna S vulcanizate will almost certainly lead to a serious tear: (1) cracking; (2) wetting with petroleum products; (3) flexing, static or dynamic.

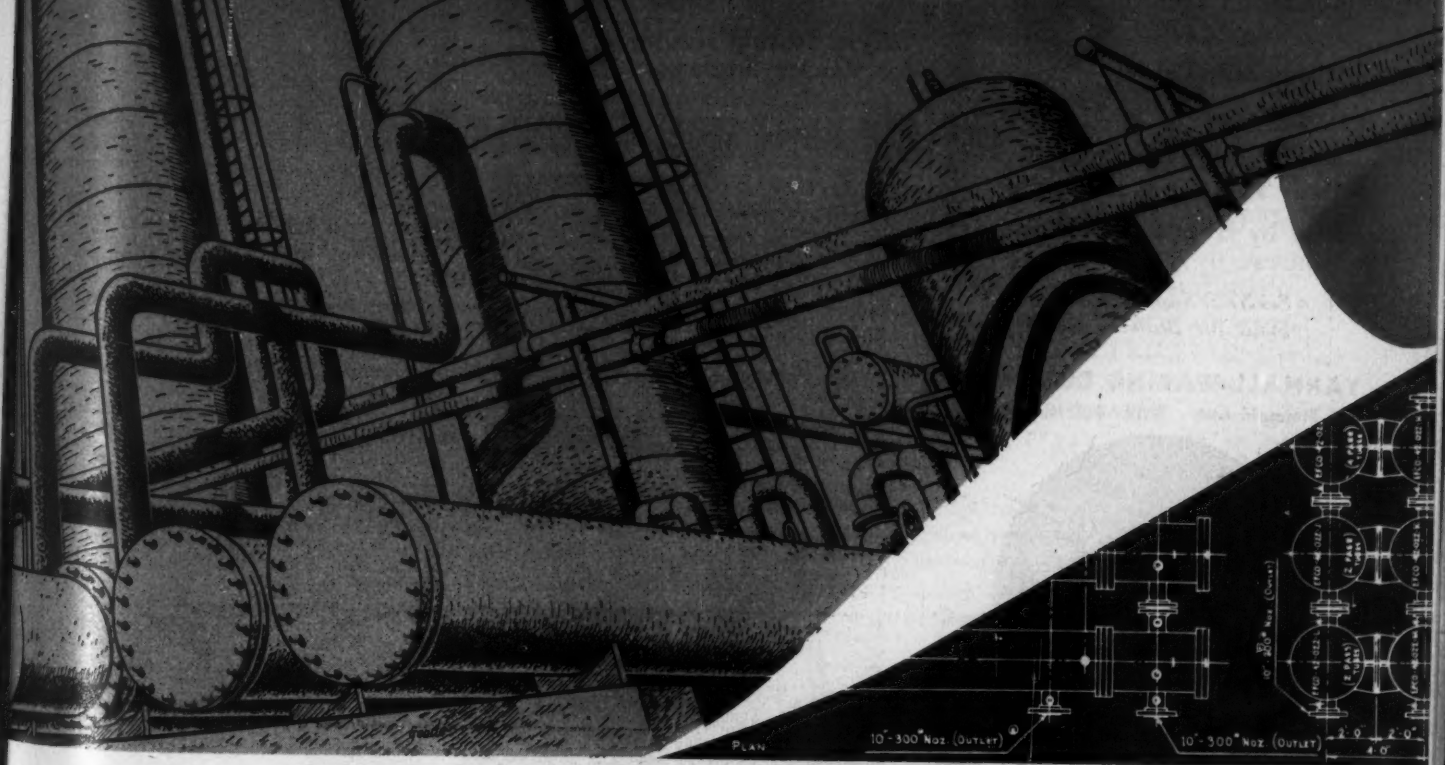
Improved Fuels to Be Post War Necessities

Post-war automobiles will be small, light-weight editions fueled by high-octane, heavily-taxed gasolines now available only for military aircraft and motorized equipment. Post-war manufacture of 100-plus octane gasolines will force engineers to design diesel engines which will get the utmost out of low-cetane fuels for railroad, marine, long-distance and overseas air cargo, and construction service.

This prediction for the post-war petroleum fuels situation was placed before the Diesel Engine and Fuels and Lubricants Meeting of the Society of Automotive Engineers in Cleveland, June 3, by Dr. C. M. Larson, chief consulting engineer, Sinclair Refining Company. He reported that high-octane aviation gasolines, explosives, synthetic rubbers, plastics, anaesthetics, and other essential war products now are being made in petroleum refineries at the expense of the kerosines and distillates from which diesel fuels are derived. He expressed the opinion that diesel fuels will be on the critical list by 1944 and said that even after the war the extremes between octanes for gasoline engines and cetanes for diesel engines will broaden in favor of high octanes to the detriment of diesel fuel ignition quality.

EFCO

Specialists in designing and fabricating superior heat transfer equipment for 100 octane gasoline and synthetic rubber plants



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- Cadmium Plated Inside and Out
- High-Grade Woven Monel Wire Screen
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- For Steam Lines or Water, Oil and Other Fluids
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- 6 Sizes from ½" to 2" for Pressures up to 600 lbs
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128 Mermaid Ave. PHILADELPHIA 18, PA.

YARWAY STRAINERS

☆ BUSINESS NOTES ☆

Brandt Directing Manufacturing For Elliott Company

Edgar C. Brandt has been elected vice president and a member of the board of directors of Elliott Company, in charge of manufacturing. He comes to the Elliott Company after 38 years of experience with Westinghouse Electric and manufacturing Company. He started with an engineering course in 1905 and came up through the organization. He was manager of several plants, was supervisor of machine tools and manufacturing methods of the company and for eight years was sales manager of renewal parts and maintenance for the entire company. He has also served the War Production Board for the past two years, one year in Washington in the equipment and production division, and one year as manager of the machine tool and equipment division in Detroit.

E. C. BRANDT

Globe Steel Tubes Adds to Personnel

C. A. Schroeder, has been appointed manager for Globe Steel Tubes Company at Cleveland, Ohio.

E. Gammeter has been made chief metallurgist, at Milwaukee, home office of the company.

Whyte Casting Salesman For Cooper-Bessemer

Dave M. Whyte, foundry expert of The Cooper-Bessemer Corporation, has been appointed supervisor in charge of casting sales of the corporation's two foundries, one at their Mt. Vernon, Ohio, headquarters and the other at Grove City, Pa.

Shortly after his arrival in this country from Scotland, where he received his schooling, Whyte worked as molder for E. W. Bliss Company. Later he became associated with the Foundry Equipment Company. During the six years he spent with the latter concern he was successively trouble-shooter, foundry technician and salesman.

D. M. WHYTE

Prior to his present appointment at Cooper-Bessemer, he served the company as assistant foundry superintendent, superintendent of the Mount Vernon foundry, and superintendent of the Grove City foundry. In his present capacity, he is in charge of the company's foundry castings sales. He has been with Cooper-Bessemer Corporation for 20 years.

Clyde B. Lynde With Industrial Insulators

Clyde B. Lynde has joined the staff of The Industrial Insulators, Houston, and will have charge of sales and execution of applied insulation contracts. For 10 years he was in charge of the contract department of Eagle-Picher Sales Company for applied insulation.

L. Keith Baldwin, another of the organizers of the company, has taken charge of the material sales service to the process industries in the Texas Gulf Coast area.

Harold M. Aber has taken the North Louisiana, South Arkansas and East Texas terirtory.

Mathieson Alkali Works Announces Promotion

J. B. Peake has been made assistant general manager of sales for The Mathieson Alkali Works, with headquarters in New York. He was formerly New York district sales manager. In his new capacity he will be assistant to D. W. Drummond.

Peake joined the New York office of the company in 1920, later being transferred to the Charlotte, North Carolina, district sales office from which point he opened up the Southwest territory, where Mathieson had not previously been represented. Subsequent posts held by him were district sales manager for the Chicago, Cincinnati, and New York territories.

Pittsburgh Equitable Meter Executives in Service

Four of the top executives of the Pittsburgh Equitable Meter Company, Pittsburgh, are participants in various branches of governmental service.

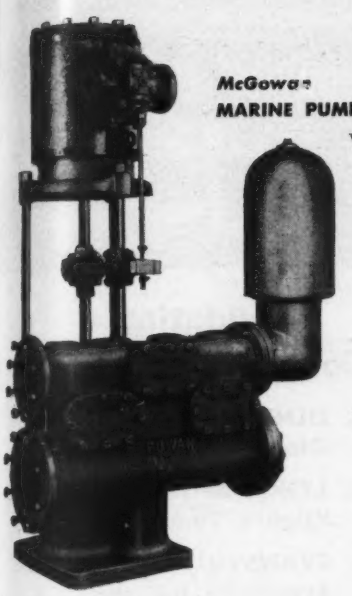
Colonel Willard F. Rockwell, president, who has been in the Army Reserve over 20 years, has been serving as director of production for United States Maritime Commission in Washington, since April 7, 1942. In this capacity, he is in charge of the production requirements for cargo vessels. He is a member of the executive committee of the Army and Navy Munitions Board, the

W. F. ROCKWELL

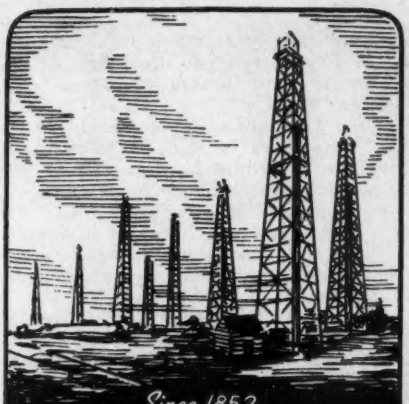
W. F. ROCKWELL, JR.

A. E. HIGGINS

A. D. MacLEAN



McGowan MARINE PUMPS

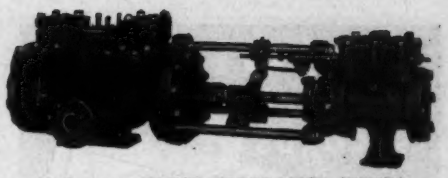


Since 1852

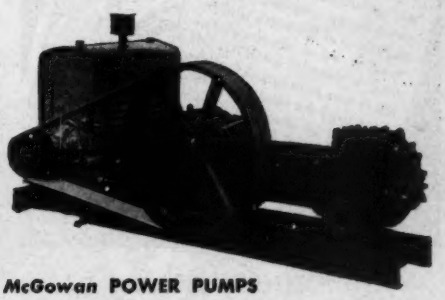
McGOWAN PUMPS for the Petroleum Industry

DUPLEX and SIMPLEX

The McGowan Pump Division of the Leyman Manufacturing Corporation guarantees accurate workmanship and durable service. An experienced Engineering Department is available for information on installations and requirements. Highly efficient and ruggedly constructed — McGowan Pumps have the ability to stand up year in and year out under severe service conditions.



McGowan CLOSE CLEARANCE PUMPS



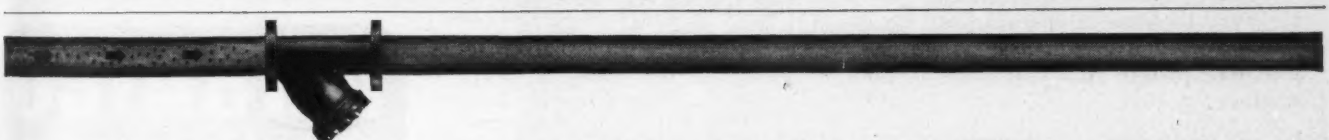
McGowan POWER PUMPS

McGowan PISTON PACKED VALVE PLATE PUMPS

McGowan PISTON PACKED VALVE PLATE PUMPS

58 Central Avenue
Cincinnati, Ohio

McGowan Pumps · Division of the LEYMAN MANUFACTURING CORP.



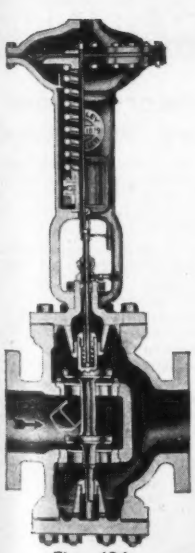


Fig. 484

Got a Control Valve Problem? CALL ON K & M

War has curtailed our civilian manufacturing—and multiplied the difficulties of your job. But don't let it get you down. If you have a problem involving pressure or fluid control — an installation, operating or maintenance problem — we can save you days of work and worry. Call on our new VALVE PROBLEM CLINIC. All the know-how of 65 years of specialization is yours for the asking . . . no charge, no obligation, no red tape. Whether or not you are using K & M equipment . . . we invite you to CALL ON K & M.

K & M DIAPHRAGM MOTOR VALVE—*for controlling pressure or flow of oil, steam, gas or air—or for use in conjunction with air operated instruments or auxiliary pilot units. Highly sensitive—single or double seated—sizes ½" to 12". Furnished with K & M exclusive "Alignment Suspension" upper structure to minimize friction and functional unbalance.*

KM KIELEY MUELLER ESTABLISHED 1879

Kieley & Mueller

ENGINEERED PRESSURE & FLUID CONTROL SPECIALTIES

NORTH BERGEN, NEW JERSEY

Representatives in all Principal Cities

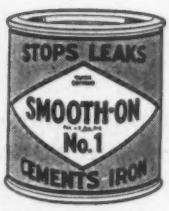
SMOOTH-ON
REPAIR
RECORDS
Repair of Cracked Pump
The surface of the crack in this pump casing was cleaned and the edges of the crack slightly beveled by a sharp-pointed tool. A putty of SMOOTH-ON No. 1 was then forced into the crack until the crack was filled. No heat or dismantling was required, and the pump was again ready for use as soon as the SMOOTH-ON hardened.
FOLLOW THIS SERIES OF SMOOTH-ON SAVINGS

When SMOOTH-ON No. 1 is forced into a crack, its expansive property wedges it tightly between the confining surfaces, thereby providing a pressure-tight seal. Moreover, SMOOTH-ON becomes even stronger with age.

This many-purpose iron repair cement has been used by refinery engineers and maintenance men for almost half a century for sealing cracks and stopping leaks in apparatus.

War-time conditions make SMOOTH-ON more of a plant necessity than ever before. Be sure to have a can handy so you will be prepared to repair equipment that you can't replace.

Buy SMOOTH-ON in 7-oz., 1-lb., or larger containers from your supply house, or if necessary from us. For your protection, insist on SMOOTH-ON, used by engineers and repair men for over 45 years.



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REPAIR HANDBOOK SHOWS HOW

40 Pages, 170 diagrams, and simple concise instructions for practical repairs to plant equipment, pipe lines and structures. A necessity in every plant. Your copy sent FREE if you fill in and return the coupon.

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Do it with **SMOOTH-ON**
The Iron Repair Cement of 1000 Uses

material requirements committee and scheduling committee of WPB, as well as serving on numerous other committees.

Allen D. MacLean, vice president and chief engineer, is also in Washington with the Maritime Commission serving as assistant director of production.

Private W. F. Rockwell, Jr., vice president and comptroller, is in training at the Army Ordnance Officers' School, Aberdeen Proving Grounds, Aberdeen, Maryland.

Captain A. E. Higgins, vice president and sales manager, a Reserve Officer of many years standing, has been commissioned a major and assigned to active duty with the Air Corps.

Westinghouse Announces Two New Vice Presidents

Fred T. Whiting and Charles A. Dostal, district managers for Westinghouse Electric and Manufacturing Company, have been elected vice presidents. Whiting is in charge of the Chicago territory with headquarters in Chicago, and Dostal, the Pacific Coast District with headquarters in San Francisco. Duties and headquarters of both men are unchanged. As Northwestern District manager since 1930, Whiting has directed the company's sales activities in a territory which includes parts of 10 states. Dostal has been Pacific district manager since 1939, directing the company's sales activities in all or parts of 11 western states and in Alaska and the Hawaiian Islands. He has been with the company for nearly 37 years.

King Now Executive Engineer With Worthington

Marcello A. King has joined the Worthington Pump and Machinery Corporation as executive engineer of the Moore Steam Turbine Division, Wellsville, New York. He will be in charge of design, research, testing and service. Engaged in turbine engineering and manufacture since his graduation from the University of Michigan in 1916, he was with the Kerr Turbine Company and later with Elliott Company where he held the position of manager of engineering.

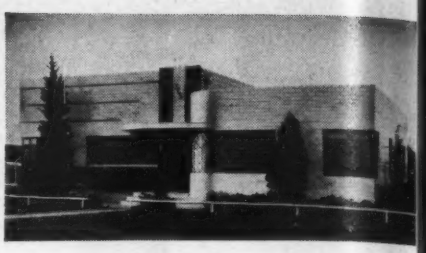
Yezbak in Charge of Timken News Bureau

John J. Yezbak is now in charge of the news bureau of Timken Roller Bearing Company, Canton, Ohio. He succeeded S. L. Huffman, who resigned.

J. S. Carroll, Johns-Manville Vice President, Retires

Retirement of J. S. Carroll, vice president of Johns-Manville, has been announced. He has been associated with the company 32 years, first as sales representative in the Philadelphia district, later as architect's representative in the New York headquarters. In 1915 he was appointed sales manager of Metropolitan New York. Because of his success in serving the oil companies in the Metropolitan area, he was given the re-

J. S. Carroll



Liquidating 4 Complete Refineries

1. **OLNEY REFINING CO. Olney, Texas**
2. **LYNCH REFINING CO. Kilgore, Texas**
3. **EVANSVILLE REFINING CO. Evansville, Indiana**
4. **TITAN REFINING CO. Stark, Michigan**

Complete stocks refining equipment, valves, and fittings. Immediate delivery from our Tulsa Warehouse.

Refinery Equipment, INC.
UNION AVE. AT 21st STREET
TULSA, OKLA.

PLIBRICO
Jointless **FIREBRICK**

The Answer to Your Refractory Problems!

FOR boilers and stills—for patching and repairs—for entire walls and complete relining—Plibrico Jointless Firebrick is the dollar-saving, trouble-saving refractory that refineries everywhere are adopting.

Plibrico forms a solid, monolithic lining that eliminates the weak joints of laid-up fire brick construction. Flexo-Anchors prevent bulging. No special shapes are required; Plibrico comes in moist, plastic form and can be readily moulded to any shape. Your own maintenance men can install it or we furnish complete installation service.

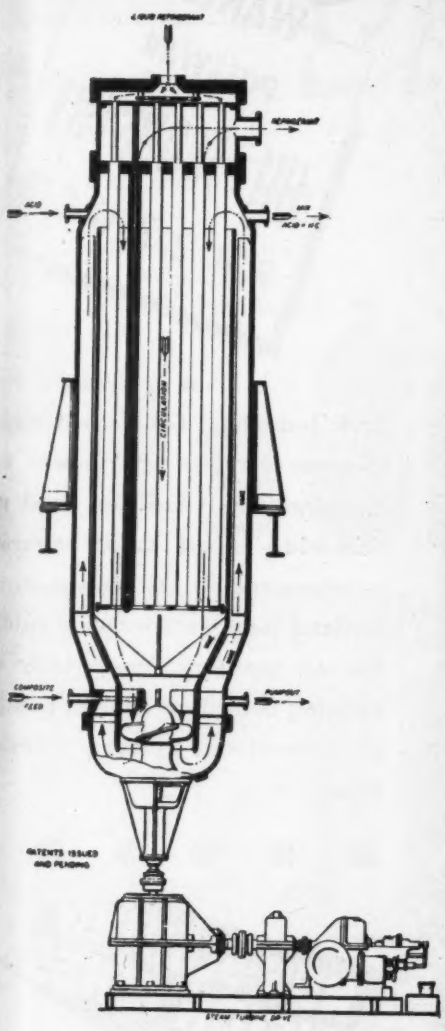
For extreme conditions, there is the Plibrico sectionally-supported air-cooled wall. And the Plibrico suspended arch for boiler arches and still roofs. Both are erected without special tile or heavy castings.

These catalogs cover your requirements.

Here is the complete story of Plibrico linings, arches, air cooling, etc. Ask for your Plibrico catalog. Specify whether operating H.R.T. or water tube boilers.

PLIBRICO JOINTLESS FIREBRICK CO.
1803 Kingsbury St., Chicago, Illinois

STRATCO ALKYLATE



STRATCO ALKYLATION CONTACTOR

Higher Yield
Higher Octane

Result:

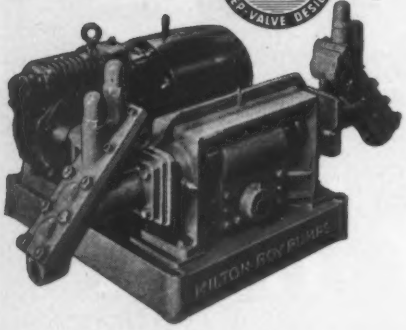
MORE FIGHTING FUEL

STRATFORD ENGINEERING CORPORATION

PETROLEUM REFINING ENGINEERS

DIERKS BLDG. KANSAS CITY, MO.

MILTON Roy
Step-Valve PUMPS
WITH THE EXCLUSIVE STEP-VALVE DESIGN



Synthetic Latex
Can be Pumped
in *Precisely*-Controlled Volume

Milton Roy Pumps *prove* that synthetic rubber latex can be pumped, with minimum turbulence, in precisely-controlled volume, with only usual operating attention. Goodyear engineers selected this pump . . . installed the first of them more than two years ago . . . say they are performing this most difficult job with entire satisfaction.

Hundreds of Milton Roy Pumps, standard and "special" units, are in use . . . in refining, chemical, processing and other services . . . handling

- DISTILLATES
- ALKALIS
- ACIDS
- SLUDGE
- BUTANE
- ETHYLENE
- GLYCOL
- PROPANE
- TAR
- ASPHALT

The Milton Roy Step-Valve (patented) is self-cleaning and non-clogging . . . it functions, dependably, with little or no attention. It has no pockets in which air-bubbles can form . . . there's no air-binding, no wire-drawing. It will give you precise control of volume, down to one pint or less per hour and up to full rated capacity. It is built in corrosion-resistant metals, for practically all chemical services; also for hydrostatic testing and other high pressure services, up to 20,000 lbs. per sq. in.; may be jacketed for temperature control.

Our engineers are ready to consult with you about specific applications. Our Catalog and Bulletins describe Milton Roy Pumps, fully.

If we can help your war effort 'phone or write

MILTON Roy PUMPS
1393 E. MERMAID AVE., CHESTNUT HILL, PHILA., PA.

sponsibility of forming a department to service the oil industry throughout the United States. In 1923 he was elected vice president of the company.

Carroll has played an important part in the development of conservation of fuel in the oil industry as well as the conservation of gasoline while in storage. He is a former director of the American Petroleum Institute.

He was born in St. Louis in 1872. After attending public and private schools he passed the examination for entrance to West Point. His father's death, however, changed his plans and he entered the construction field. For several years he occupied executive and engineering positions with large industrial constructors including the Westinghouse Electric and Manufacturing Company. In 1911 he joined Johns-Manville.

Just before his retirement a large group of his friends in the purchasing and engineering professions assembled at the Biltmore Hotel, New York, to give a dinner in his honor. He plans to pass his retirement in California where he has set up a permanent residence.

Foster to Sales Post Of Pittsburgh Equitable

Donald B. Foster has been appointed assistant sales manager of the Pittsburgh Equitable Meter Company. He was formerly district manager for the Pittsburgh territory. In his new capacity he will be acting head of the sales division for both the parent concern and subsidiary, Merco Nordstrom Valve Company. He is a native of Pittsburgh and a graduate of Carnegie Institute of Technology.

D. B. FOSTER

Fred M. Young Joins Western Metals Company

Fred M. Young has been appointed vice president and a director of Western Metals Specialty Manufacturing Company, Milwaukee, Wisconsin. He is also president and general manager of Young Radiator Company and will continue to devote the greater part of his time to that organization.

John H. Kunkel Is Vice President of NIAA

John H. Kunkel, director of public relations and advertising manager of The Fluor Corporation, Ltd., Los Angeles, has been elected vice president of the National Industrial Advertisers Association. He also is a member of the board of directors of the association.

Kunkel is serving his second term as president of the Los Angeles chapter, Industrial Advertising Association of Southern California.

J. H. KUNKEL

The Bristol Company Makes Two Promotions

The Bristol Company, Waterbury, Connecticut, announces the following promotions:

E. Nuber has been appointed manger of the Pacific Coast branch offices and factory, San Francisco.

Nuber joined the company in 1929 as sales engineer and since then has represented it at Boston, Akron, Waterbury, Birmingham, Chicago, and Los Angeles at various periods. Before be-

WANTED
POSTWAR
OIL INDUSTRY
PRODUCT

● A Central New York Industrial Equipment Manufacturer having light steel and machine shop facilities and nation-wide direct sales coverage is interested in securing a standardized item for postwar sale to the oil industry, preferably the refining branch. Address, Box 38, c/o Petroleum Refiner, Houston, Texas.

NON-SCORING PISTON RINGS
"BAKORINGS"
SAVE LINERS

Plastic material of these piston rings is practically self-lubricating, hence temporary loss of lubricant will not affect life of liners or rings. Plastic allows grit and scale to become embedded saving liners from abrasive scraping.

Basic material made by General Electric Co.
Leading companies find Bakorings save money.

Quick Delivery . . . Write for Folder and Prices

BAKORING
INCORPORATED
1020 HOUSTON AVENUE
HOUSTON, TEXAS

PROTECT YOUR WORKERS NOW

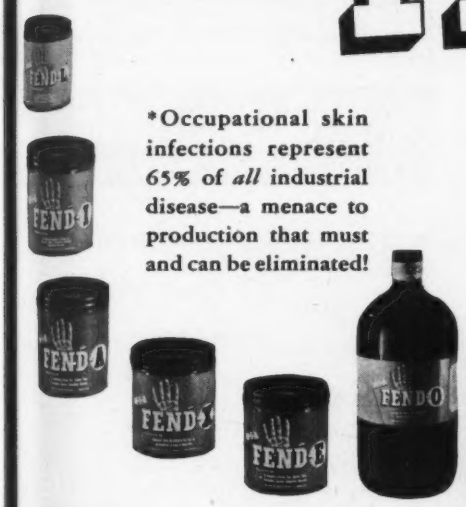
AGAINST THE **MAJOR CAUSE*** OF ALL OCCUPATIONAL DISEASES

WITH **M·S·A** **FEND**

MINE SAFETY APPLIANCES CO.

BARRIER PROTECTION

For the Worker's Skin



*Occupational skin infections represent 65% of *all* industrial disease—a menace to production that must and can be eliminated!

In the broad FEND line of industrial creams and lotions, you'll find the right protection against skin irritations encountered in the modern refinery—easy to apply and remove—bland and neutral—medically correct and cosmetically safe to use under all conditions. FEND Creams bar the way to skin irritation—keep your workers safe on-the-job. Write for complete descriptive details!

MINE SAFETY APPLIANCES COMPANY
BRADDOCK, THOMAS AND MEADE STREETS
PITTSBURGH, PA.

CALAPOR

CAPTAIN PRODUCTS

INSULATIONS
LIGHT IN WEIGHT . . . EFFICIENT

SPECIALTIES
ADAPTABLE TO SERVICE

CALAPOR MANUFACTURING CO.
Office: Hibernia Building, New Orleans, La.
Factory: 5521 Clinton Drive, Houston, Texas

YOUR ANSWER for speeding wartime MAINTENANCE

Descale Compressors Faster, Easier!

Today, water-cooled air and gas compressors must operate longer . . . and at peak efficiency . . . to help meet the Nation's war demands!

Careful maintenance is a MUST! First of all, don't permit lime-scale or rust deposits to build up in water jackets to reduce heat transfer and impair efficiency. Instead, get rid of these deposits THOROUGHLY, QUICKLY with Oakite Compound No. 32! Used as directed, it completely removes insulating accumulations . . . speedily restores normal heat transfer!

Send for FREE Booklet!

FREE, 24-page booklet describes time-saving Oakite methods for descaling compressors, Diesel engines, condensers, coolers, steam generators, reboilers, etc. Send for YOUR copy TODAY!

OAKITE PRODUCTS, INC.
50B Thames Street, New York
Technical Service Representatives Located in All Principal Cities of the United States and Canada

OAKITE Specialized CLEANING

Buy Bonds for Victory

E. NUBER

J. W. PECKHAM

ing appointed to his new position he was manager of the Akron branch office and factory.

J. W. Peckham has been appointed manager of the development and design engineering department at Waterbury. In 1922 he joined the company's radio engineering department. In 1940 he was appointed Pacific Coast district manager, in charge of the company's San Francisco, Seattle, and Los Angeles offices and San Francisco branch factory.

Roy L. Stone Joins Cochrane Corporation

Roy L. Stone has been appointed flow meter representative for Cochrane Corporation, with offices in the Commerce Building, Rochester 4, New York, and 295 Hartford Avenue, Kenmore 17, Buffalo, New York.

MERIT AWARDS

Awards of merit have been made by the government to the following firms:

Bonney Forge & Tool Works, Allentown, Pennsylvania, white star added Army-Navy E for meritorious services on the production front, signifying second award.

Great Western Division of Dow Chemical Company, Pittsburgh, California plant, Army-Navy E for high achievement in the production of war materials.

Philadelphia Gear Works, Philadelphia, Army-Navy E for outstanding production of gears and other equipment for wartime use.

Air Reduction Oxygen Plant of Air Reduction Company, Bethlehem, Pennsylvania, Maritime M and Victory Flag for outstanding production achievement.

The Babcock & Wilcox Company, Refractories Division, Augusta, Georgia, white star to Army-Navy E, signifying second award, for continued excellence in production of war materials.

Alloy Steel Products Company, Linden, New Jersey, Army-Navy E on excellence in essential war production of steel valves and fittings.

Homestead Valve Manufacturing Company, Coraopolis, Pennsylvania, gold star added to Maritime M pennant signifying continued outstanding achiev signifying continued outstanding achievement in the production of vital war products.

Brown Instrument Company, Philadelphia, Army-Navy E award for effectively contributing to the great goal of victory through development of devices for the United States Navy.

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